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Core Inflation

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ABSTRACT

The Bank of Canada uses *core* CPI inflation, the year-over-year rate of change of the consumer price index excluding food, energy, and the effects of changes in indirect taxes, as the operational guide for monetary policy. In this report we study the concept and measurement of core or underlying inflation more generally by examining several alternative measures of core inflation, from the viewpoint that core inflation is a tool for policy purposes, either as an indicator of current and future trends in inflation, or as a viable target for monetary policy. A simple model of price determination is proposed that defines the core conceptually, and illustrates the process by which aggregate inflation rates may differ from the core.

As a measure of inflation for policy purposes, core inflation is useful to the extent that it can be measured accurately. Therefore, following a discussion of conceptual issues, the report's focus narrows and we introduce the various measures of core inflation, concluding with a comparative evaluation of those measures. We find the alternatives quite similar in many respects. However, a closer assessment based on their suitability to various policy purposes suggests that different measures do well along different dimensions.

JEL classification: E31
Bank classification: Inflation and prices

RÉSUMÉ

La Banque du Canada a recours à l'inflation *mesurée par l'indice de référence*, c'est-à-dire le taux de variation sur douze mois de l'indice des prix à la consommation hors alimentation, énergie et effet des modifications des impôts indirects, pour la guider dans la conduite de la politique monétaire. Les auteurs examinent le concept et la mesure de l'inflation fondamentale ou sous-jacente dans une perspective plus générale, en étudiant diverses méthodes possibles pour mesurer l'inflation fondamentale. Ils partent du principe que celle-ci joue un rôle utile dans la formulation de la politique monétaire, soit comme indicateur des tendances actuelle ou future de l'inflation, soit comme cible à long terme. Les auteurs proposent un modèle simple de détermination des prix, qui définit le concept de l'inflation fondamentale et illustre en quoi celle-ci peut différer du taux d'inflation global.

Aux fins de la conduite de la politique monétaire, l'inflation fondamentale est un concept utile pour autant qu'elle soit évaluée avec précision. Après une analyse des questions d'ordre conceptuel, les auteurs se concentrent sur les diverses mesures de

l'inflation fondamentale et concluent leur exposé par une évaluation comparative de celles-ci. Les différentes mesures, constatent-ils, sont à maints égards très semblables. Toutefois, un examen attentif de leur utilité pour la conduite de la politique monétaire indique que leurs mérites diffèrent selon le critère envisagé.

Classification JEL : E31
Classification de la Banque : Inflation et prix

1. Introduction

A traditional role of a central bank has been to preserve the purchasing power of money by keeping a lid on inflation. In recent years, this objective has been formalized in a number of countries by instituting explicit inflation-control targets. Inflation targeting makes the link between monetary policy and published (or headline) inflation rates more transparent to the public, thereby making central banks more accountable for policy. However, the current headline inflation rate is not totally under the control of the central bank. Policy changes affect only underlying inflationary pressures, and hence inflation rates, slowly over extended periods of time. In addition, various economic developments beyond the control of the central bank may generate short-run or transitory changes in the inflation rate. Hence, policy-makers focus on the more persistent movements in inflation. Measures of the underlying trend in inflation have been coined *core inflation*.

To implement inflation targeting, practitioners must take a stand on which inflation rate to target. Although consumer price index (CPI) inflation is the official target in Canada, it is a core measure—the year-over-year rate of change of the CPI excluding food, energy, and the effects of indirect taxes, known as *core* CPI inflation—that the Bank of Canada has officially adopted as the *operational* target for policy. This choice followed the experience of the 1970s, in which fluctuations in food prices caused by variable harvests and in fluctuations in energy prices caused by OPEC's influence had a substantial short-term impact on headline inflation rates, independent of the stance of monetary policy at the time. Although *core* CPI inflation has served well as the operational target, alternative measures of underlying inflation may be equally or better-suited to policy use. The goal of this report is to examine whether alternative measures of core inflation may be useful in the conduct of monetary policy in Canada.

A practical approach is taken. We focus on the suitability of various measures of core inflation to the policy purposes of those measures. To motivate the interest of policy-makers in alternative measures of underlying inflation, section 2 introduces the policy purposes of a measure of core inflation. Section 3 illustrates the link between monetary policy and core inflation through the use of a general model of the transmission mechanism. Sections 4 and 5 review the various approaches taken to the measure of core inflation in the literature and some of the practical issues related to its measure. The discussion narrows in section 6 to measures of underlying inflation in use at the Bank of Canada. Section 7 evaluates the usefulness of various measures for policy purposes in a Canadian context. Section 8 concludes. The appendices document technical details that supplement the discussion in the report: Appendix 1 gives numerical examples of the calculation of certain measures of core inflation used at the Bank of Canada; Appendix 2 investigates the subcomponents of the CPI; and Appendix 3 discusses the skewness and kurtosis in the disaggregated CPI data.

2. Policy Purposes of a Measure of Core Inflation

The ongoing interest in core inflation reflects its usefulness as a tool for policy. A measure of core inflation could be both a better guide for current and future policy than published inflation rates and a measure of inflation that is more controllable. Ideally, a measure of core inflation would be:

- a good indicator of current and future trends in inflation; and
- a viable target for monetary policy.

It may be that the measure of core inflation would suit one or both of these needs.

2.1 A good indicator of current and future trends in inflation

Monetary authorities closely monitor a wide range of data on the current state of the economy and the current inflation rate. This ensures that the most timely information is incorporated into policy decisions. However, since monetary policy affects inflation with long and variable lags, central banks must take a view on the future evolution of inflation. Core measures assist in the analysis of new developments by providing a means by which the monetary authority can separate the noise and short-run fluctuations in the incoming data from its more persistent trend. The most useful measures of core inflation will minimize misleading signals about current and future trends in inflation.

As an indicator, core inflation is a guide to policy-makers as to whether current policy settings are likely to achieve the target. Policy-makers may respond to the indicator at their discretion or they may take a less discretionary approach and incorporate the indicator into a policy rule. For example, Taylor rules use the current deviation of inflation from its target as a guide for policy (see Hogan 1998).

By allowing policy-makers to see through temporary or misleading fluctuations, core inflation can also be a useful tool to assess the effectiveness of past policy. It may even be a public measure that could assist in the accountability process. In this case, core measures can act as tools that aid in the communication or transparency of policy, since they may help to clarify why policy-makers are or are not reacting to recent fluctuations in published inflation rates. Its use in communication of policy could also improve public understanding of the notion that policy is linked to the more persistent movements in inflation.

2.2 A viable target for monetary policy

If price fluctuations from non-monetary sources can be excluded, the resulting core inflation could be regarded as a measure of the inflation that is the *outcome* of policy. Therefore, some measures of core inflation could be considered to be more controllable by the monetary authorities than

published inflation rates. This closer relationship suggests that core inflation might be a better target for monetary policy than headline inflation rates.

Since the use of a target implies that the monetary authority will accept responsibility for inflation *ex post,* it makes sense to define the target in terms of the measure of inflation for which it has the most *ex ante* control. This would further establish accountability for policy. Core inflation measures may be suitable as either a direct or an intermediate target.

Use of a core measure as an official target would focus public attention on the persistent trend in inflation, bringing it into line with the focus of the monetary authority. This is important since the success of inflation targeting works largely through anchoring the inflation expectations that will be incorporated into decisions and contracts. To the extent that this focus reduces the pass-through of temporary shocks to public inflation expectations, the variability of inflation would be further reduced.

Finally, there are other desirable qualities of a target measure of inflation, such as public acceptance and understanding. This latter criteria gives headline inflation rates an advantage over core measures, and suggests at a minimum that a core measure to be used as a target must be both relatively simple and acceptable to the public.

2.3 Which price index?

It is useful to briefly consider a related but distinct measurement question facing a central bank: the choice of the appropriate price index.

In an economy with only a single unchanging good or one in which relative prices between goods never changed, so that all individual prices increased at the same rate, there would be no ambiguity as to how to define the rate of inflation. In an economy with multiple goods and changing relative prices, however, each good has its own rate of price change. A price index aggregates the prices of different goods into a single number whose rate of change defines the aggregate inflation rate. Typically, a price index is defined as the price of a representative basket of goods, so that the inflation rate describes how the price of that basket changes over time. There are thus many different aggregate inflation rates, depending on which commodities are included in the basket and their relative weights.

The choice of basket and weights depends on what the index is to be used for. For instance, one reason for targeting low inflation is to maintain the real value of the currency in terms of its value to consumers, and so eliminate the need for costly indexing of contracts and the tax system. This is one reason why most inflation-targeting countries specify their inflation target in terms of the CPI, which only considers the inflation in consumer goods and services rather than spending in the economy as a whole. It is also the reason the discussion in this report is limited to measures of core inflation based on the CPI.

The reason for raising the choice of index is that, as we shall see later, many measures of core inflation used around the world operate by removing certain goods from the basket or changing the weights. That is, the measure of core inflation is simply the rate of growth of a different price index. The issues that arise in choosing the appropriate index for inflation, however, are quite different from the question of how to define core inflation, even though one technique for measuring core inflation is to choose a different index.

The selection of the CPI as the target index rather than the producer price index was based on the judgment that an index of consumer inflation should be kept low and stable as the objective of monetary policy. CPI inflation approximates increases in the cost of living, and it is the final cost of consumer goods and services that are relevant for many contracts and for the personal tax system. In addition, the CPI is often the basis for the formation of the inflation expectations that will be incorporated into household and business decisions and contracts. The CPI index measures inflation that has a direct *effect* on both businesses and consumers. However, the CPI may not be the best inflation measure to focus on for practical policy purposes. The exclusion of food and energy from the core index, for example, was not motivated by a belief that pure changes in those goods are not relevant, but rather that fluctuations in the relative prices of food and energy are typically temporary and arise as a result of *causes* not related to monetary policy.

The key distinction, then, between the question of which price index to use and how to define and measure core inflation is that the former concerns the *effects* of inflation, whereas the latter is the result of an attempt to differentiate between persistent and temporary *causes* of price changes to decide which variation of a price index should be the focus of policy. For instance, in Canada, although the formal inflation targets are expressed in terms of the headline CPI, the Bank of Canada is explicit that, in seeking to implement the targets, it focuses on a core measure commonly referred to as *core* CPI inflation (denoted as CPIxFET inflation in this report), which excludes food, energy, and the effects of changes in indirect taxes (see *Bank of Canada Review* 1991b).

Because of this emphasis on causes rather than effects, it is important to carefully specify the inflation-generating process when seeking to define and measure core inflation. See Eckstein (1981) and Parkin (1984) for an early debate on the definition of core inflation.

3. A Model of Inflation Determination

At its most general level, the concept of core inflation rests on the premise that in the long run it is monetary policy that determines the price level, but that in the short run non-monetary factors can cause temporary deviations of the price level from that long-run trend. We model this using a version of the standard Ball (1997) and Svensson (1997) model of the transmission mechanism in a closed economy, adapted as a monthly model to correspond more closely to the actual frequency over which policy decisions are made:

Aggregate demand $$y_t = -\gamma(L)[(i_t - \pi^e_t) - r^*_t] - G(L)(y_t) + \delta_t \quad (1)$$

Phillips curve $$\pi_t = (\alpha\pi^e_t + (1-\alpha)\beta(L)\pi_t) + \lambda(L)(y_t) + \varepsilon_t \quad (2)$$

Potential output $$y^*_t = \bar{y}_t + \sigma_t \quad (3)$$

Reaction function $$(i_t - \pi^e_t) = \varphi(L)(i_t - \pi^e_t) + \theta(\pi_t - \pi^T_t) + \zeta(y_t - \bar{y}_t) + \xi_t \quad (4)$$

Equation (1) is a standard IS curve that relates the output gap $y_t = y_t - y^*_t$ to lags of a real interest rate gap and its own lagged values; y_t is the gap between output and potential output in the economy at time t; i_t is the monetary policy instrument, here identified with the nominal interest rate; π^e_t is the expected future rate of inflation at time t; and r^*_t is the equilibrium real interest rate. Throughout the model, lag operators are used to denote lags at a monthly frequency, for example, $\gamma(L) = \gamma_1 L + \gamma_2 L^2 + \ldots + \gamma_n L^n$ is a polynominal lag operator that captures lags in the real interest rate gap. The lag in the monetary instrument represents the time that it takes monetary policy to affect demand. The evolution of inflation is represented by equation (2), a Phillips curve, where inflation depends upon the lagged output gap. The presence of the term $(\alpha\pi^e_t + (1-\alpha)\beta(L)\pi_t)$ reflects the view that inflation is both a function of forward-looking expectations of future inflation and of the momentum built into the inflation rate at the time. This momentum reflects past inflation as well as the fact that it takes time for inflationary impulses to work through the production chain of intermediate goods. In effect, cost-push influences continue to act on inflation for some time after an initial impulse. Equation (3) is added for clarification; it defines actual potential output y^*_t as the sum of the monetary authorities' measure of potential $\bar{y}_t$ and σ_t, the error in estimating the potential supply in the economy; σ_t is I(0). Equation (4) is a Taylor rule, where monetary policy is conducted such that the real interest rate, $i_t - \pi^e_t$, is a function of the past real interest rate, the deviation of actual inflation from its target, $\pi_t - \pi^T_t$, and the measured output gap $(y_t - \bar{y}_t)$.

The error terms represent uncertainties facing a central bank: The measurement error, σ_t, which can be thought of as a "supply shock," represents the inherent difficulty in measuring potential output; while the demand shock, δ_t, captures the uncertainty in the relationship between the monetary-policy instruments and aggregate demand. The shock term, ξ_t, captures monetary shocks.

The distinction between aggregate supply and demand shocks and price shocks, ε_t, is one of timing. Aggregate demand and supply shocks affect inflation with a lag, whereas price shocks have an immediate effect on the measured inflation rate. The relevance of price shocks to monetary policy depends in part on whether they are permanent or transitory. To formalize this, we decompose the price-shock term in Equation (2) into two components: $\varepsilon_t = \mu_t + \eta_t$. The first component, μ_t, captures the effect of temporary relative-price shocks, such as those affecting the volatile components of food and energy. This component will also pick up any random

measurement error in the inflation rate. The second component, η_t, arises from I(1) shocks to the price level, and hence I(0) shocks to inflation. It represents permanent relative-price shocks. For our purposes, we can define permanent as any shock that lasts for a period of time greater than the monetary policy lag, say 24 months. This decomposition of the price shock suggests two definitions of core inflation:

$$\pi_t^{c_1} = (\alpha\pi^e{}_t + (1-\alpha)\beta(L)\pi_t) + \lambda(L)(y_t) + \eta_t \quad \text{; or, equivalently, } \pi_t^{c_1} = \pi_t - \mu_t \tag{5}$$

$$\pi_t^{c_2} = (\alpha\pi^e{}_t + (1-\alpha)\beta(L)\pi_t) + \lambda(L)(y_t) \quad \text{; or, equivalently, } \pi_t^{c_2} = \pi_t - \mu_t - \eta_t. \tag{6}$$

The first of these definitions removes from headline inflation price-level shocks that are temporary and hence inflation shocks that will reverse. Such shocks should not feed through into permanent changes in inflation expectations, and so can be thought of as noise. The second core definition removes all influences on the inflation rate that are not due to expectations or an output gap. It is clearly desirable to remove the effect of reversible price shocks from the headline rate in measuring core inflation, as these shocks represent noise in the long-term inflation process. This suggests seeking to obtain a measure of $\pi_t^{c_1}$. In some circumstances, it may also be desirable to remove one-time permanent price shocks, particularly if it is thought that these are well understood by the public as level shocks and will therefore not feed through into inflation expectations. In this case, $\pi_t^{c_2}$ would be the preferred indicator.

If the benefits of a stable and predictable inflation rate that motivate the policy of inflation targeting apply more to the underlying inflationary pressures than to the headline rate, core inflation may be useful as the final target of monetary policy. This would be the case, for instance, if the objective of monetary policy was to provide an environment in which people could plan for horizons of several years, in which case *reversible* price-level shocks that affect headline inflation for a limited period of time would not be a concern. In this case, $\pi_t^{c_1}$ would be the preferred target measure of inflation.

Finally, even if stability in headline inflation is the final target of monetary policy, it may still be advantageous for central banks to target core inflation as an intermediate target. First, even if it is the headline CPI in which low and stable inflation is desirable, offsetting the temporary fluctuations in inflation arising from price shocks may be too costly in terms of output variability. Hence, $\pi_t^{c_2}$ might be a preferred target measure. Second, as noted above, price-level shocks represent influences on the headline inflation rate that are beyond the control of the central bank. If the bank is to be held accountable for maintaining inflation within a target band, it may be useful for the target measure to be defined in such a way that it excludes shocks that are considered to be out of the central bank's control. Again this suggests defining the inflation target in terms of $\pi_t^{c_2}$. This could also enhance the central bank's credibility, since removing influences that are outside its control should result in less variability in inflation relative to the inflation target.

So far, our discussion has focused on the definition and uses of core inflation. As a practical matter, the measurement of inflation can only approximate one of these definitions. In the next sections, we introduce the various methods that have been used to isolate measures of core inflation.

4. Alternative Approaches to the Measurement of Core Inflation

Research on core inflation in the 1990s can be thought of as following two broad approaches that roughly correspond to focuses on the two main problems in the core inflation literature. These are:

- the modelling approach, which focuses on the conceptual problem: How do we define core inflation?
- the statistical approach, which focuses on the practical problem: How can we measure core inflation?

Ideally, a measure of core inflation would *both* define core inflation and directly exploit the data in its measurement.

4.1 The modelling approach

The modelling approach takes as its starting point a behavioural definition of core inflation. This approach is associated with Quah and Vahey (1995), who acknowledge the importance of a theoretical definition for core inflation and use the notion to determine the long-run restrictions in their model. Quah and Vahey estimate U.K. inflation with a two variable structural vector autoregression (SVAR) containing the change in inflation and the change in output, used to define core and non-core movements in inflation. One criticism of this methodology is that of misspecification, or more specifically that the lack of a complete set of explanatory variables may be affecting the results. Other researchers who have come up with alternative SVARs based upon the original Quah and Vahey approach include Blix (1995), Gartner and Wehinger (1998), Claus (1997), Bjornland (1997), Dewachter and Lustig (1997), and Fase and Folkertsma (1996). Each of their papers tries to address some criticism of the SVAR literature or of its application to core inflation. Other models of inflation have been proposed and may be notionally linked to the core inflation literature. For example, P-star, or the long-run equilibrium level of prices in standard P-star models, could be interpreted as the price level that corresponds to core inflation. (Hallman, Porter, and Small (1989), Armour et al. (1996), and Attah-Mensah (1996) have developed versions of the P-star model.)

The modelling approach involves an attempt to define core inflation and to use a model to make it operational. This approach provides the advantage that it draws a direct link between policy and core inflation as the inflation that is controllable through policy. This link makes it clear why the monetary authorities would care about this measure of inflation. The main drawback of a model-based definition of core inflation is that the resulting measure of core inflation will likely be quite

sensitive to the assumptions underlying the model. Assumptions about the flexibility of prices, about the formation of inflation expectations, and about the nature and distribution of price shocks will drive the results in the model. Moreover, the concept would be difficult to communicate. Furthermore, the arrival of new data will result in a change in the historical core inflation series produced by the model. As a whole, the sensitivity of the results would undermine the credibility of the core measure in public discussions and make it unsuitable as a target for policy, particularly since it is likely that a core inflation series based on an economic model would be generated directly by the policy-maker rather than by a statistical agency. These features limit the use of these measures of core inflation to roles as indicators of core inflation.

Even in its role as an indicator of future trends in inflation, disadvantages arise because the core measure is dependent on its theoretical context. The data are no longer exogenous, a feature that complicates model evaluation. Furthermore, the empirical implementation of any model-based core measure including VARs will be subject to degrees-of-freedom problems once various relative price shocks have been taken into account. This suggests that if one wants to deal with many types of shocks—admittedly with priors—there may be advantages to the statistical approach.

4.2 The statistical approach

Researchers using the statistical approach focus directly on the problem of how to measure core inflation using existing data. They typically take published price indexes and inflation rates as a starting point and ask how the available data can be exploited to provide a core measure. Measures of core inflation at the Bank of Canada have been constructed using this practical approach (Laflèche 1997a, 1997b).

The main advantage of this approach is that it makes full use of the range of available data on price changes. Also, when the measure of core inflation is derived using a straightforward, non-subjective technique, it is better-suited for public discussions of policy and to evaluate models of the inflation process.

A feature of this approach to date is that none of the measures have been motivated by a specific model. We would nevertheless argue that the choice of technical methods used to identify the core and non-core components has been guided by a general model of price determination similar to the one outlined earlier. Recall that this model identified two sorts of price changes that may be excluded from a measure of core inflation, where each type corresponds with one of the two components of the error term in the Phillips curve ($\varepsilon_t = \mu_t + \eta_t$).

The first component, μ_t, captures temporary price changes. These are fluctuations in prices to which the monetary authority will not wish to react simply because they are likely, by their volatile nature, to be quickly reversed on their own. Seasonality, the infrequent survey of particular prices, the timing of particular price changes, and other events may introduce noise into published

price indexes at lower than annual frequency. These core inflation measures attempt to abstract from this noise.

The second component, η_t, represents permanent changes to the price level. This implies that they will also be temporary, though possibly prolonged, shocks to the inflation rate. These are price fluctuations arising from sources beyond the control of the monetary authority. These price shocks will be idiosyncratic to the markets they originated in and can be thought of as shifts in relative prices. Examples include changes in supply which might generate large changes in the relative price of a particular good or service, changes in taste which might also lead to a change in demand for a particular product and hence a sharp change in its relative price, or specific events such as changes in indirect taxes. One-time shifts in the level of the real exchange rate owing to non-monetary sources could also lead to shifts in relative prices.

As noted earlier, this decomposition of the price shock provided us with two definitions of core inflation: $\pi_t^{c_1}$, and $\pi_t^{c_2}$, where the first measure excluded only the first type of price changes and the second excluded both types. To a varying extent, each of the statistical measures of core inflation tries to approximate one of these measures of core inflation. They each use the available attributes of data to determine whether the price change can be considered part of the core or non-core component of inflation. Where they differ is in the level of aggregation of the data used to create the distribution of price changes, as well as the period over which the properties of the distribution of price changes are evaluated.

In the next few sections, we introduce the approaches used to measure core inflation in general, and the measures used at the Bank of Canada in particular. Then, to determine whether these measures accurately capture core inflation, we conduct a comparative assessment of the various measures.

Research on statistical measures of core inflation can be divided into two branches, which effectively correspond to the use of aggregated and disaggregated data. Within the disaggregated approach, there are two types of inflation measures: those that use the distribution of inflation at a point in time, and those that use the time-series properties of the data.

4.2.1 Aggregate approach

The first branch of the statistical approach is one that uses the full sample of aggregate data and statistical techniques, typically aggregate filters, in which the inflation series is smoothed to uncover a trend. This approach focuses exclusively on the information contained in the dynamics of the aggregate index.

Research along these lines includes simple averaging, as is done with year-over-year calculations or averages over other horizons and seasonal adjustment, as well as more sophisticated filters, such as those of Cogley (1998). Statistics Canada publishes the CPI monthly, and reports

both the monthly and the year-over-year inflation rate calculated from it. The year-over-year CPI can be thought of as a very simple measure of core inflation, as it applies a 12-month, one-sided, moving-average filter to the monthly inflation rates.

4.2.2 Disaggregated approach

The second branch of the statistical approach uses disaggregated price change data to create a measure of the general increase in prices, or core inflation.

Research using the disaggregated approach includes the various papers on the weighted median and other limited information estimators by Bryan and Pike (1991); Bryan and Cecchetti (1993a, 1993b, 1996); Bryan, Cecchetti, and Wiggins II (1997); Cecchetti (1996); Roger (1995, 1997, 1998); and Shiratsuka (1997). Note that an element of time-series smoothing remains in this approach, since the cross-sectional subindexes are actually inflation rates calculated over some horizon, such as year-over-year growth in an individual component of inflation. Measures of core inflation used at the Bank of Canada are based on this approach. These measures are proposed in Crawford, Fillion, and Laflèche (1998) and Laflèche (1997a, 1997b).

- ***Disaggregated approach using the cross-sectional distribution of inflation at a point in time***

An aggregate price index, such as the CPI, is the weighted average of many individual subindexes at any particular time period, *t*. One version of the disaggregated approach focuses exclusively on the cross-sectional distribution of the individual subindex. In these measures, large or volatile movements in particular subindexes are compared to some threshold, such as the standard deviation of the distribution. Fluctuations beyond some threshold are interpreted as non-representative or idiosyncratic movements in individual prices, and are excluded from the measure of the aggregate tendency in prices.

The removal of a subindex may be justified by some factor other than its volatility. It may be useful, for example, to exclude changes in mortgage interest costs from a core measure used for policy purposes, since changes in interest rates by the monetary authorities will directly affect published inflation rates through corresponding changes in mortgage interest costs. In other cases, it may be more revealing of the trend in inflation to abstract from the effect of some event, such as a one-time change in indirect taxes on a particular price index.

Once a subset of the distribution is excluded, the remainder of the distribution is reweighted so that the weights sum to one. The weighted mean of the remaining subindexes is calculated and interpreted as core inflation. In some cases, the high variance subset is downweighted rather than excluded. By implication, movement in each non-core component either represents noise or is interpreted as non-core price shocks. The subindexes that are included in the core inflation part will in general differ from period to period.

- ***Disaggregated approach using the time-series properties of the data***

Other statistical measures use the full sample to derive a measure of underlying inflation from all existing data. Transitory movements are identified as either noise or one-time-only relative price shocks, where the latter are usually assumed to correspond to supply shocks. In contrast to the cross-sectional approach, the same components are eliminated each period (for example, food and energy). Note that the use of volatility as a criteria for exclusion implies that the components are at some time eliminated from both extremes of the distribution of price changes.

Unfortunately, transitory movements can only be perfectly identified with the benefit of hindsight. To get around this problem, this research uses the broad historical time-series properties of the subindexes to determine the candidates for exclusion. These properties may not persist into the future, so these measures ought to be re-evaluated occasionally.

5. Practical Issues in the Measurement of Core Inflation

5.1 Which approach to take?

Aggregate time-series approaches to measuring core inflation have been hampered by changes in the Canadian inflation process. There is evidence of regime changes in the Canadian data (Ricketts and Rose 1995). The most recent of these shifts occurred in the early 1990s. Year-over-year growth in the CPI fell from an average of 4.7 per cent for the 1986 to 1991 period to 1.4 per cent for the 1992 to 1998 period. Moreover, evidence on the time-series properties of the data suggest that this regime switch may be more than a shift in the mean. In particular, research suggests that the inflation process was non-stationary in earlier periods, but is now stationary in the recent inflation-targeting environment (St-Amant and Tessier 1998). These results must be interpreted cautiously, because of the low power of the test and the short period used for the analysis. Nonetheless, this evidence is consistent with the introduction of a credible inflation targeting regime in the 1990s. Close review of the individual prices that make up the aggregate price index suggests that this regime change may have occurred in a wide variety of prices. Almost all of the disaggregated prices in the CPI have lower means and most have smaller standard deviations in the period after 1992 than in the earlier period (see Table A2.1).

Use of the empirical modelling approach is made difficult by this recent historical experience. Once a researcher has adjusted for regime changes and other important temporary shocks (such as the introduction of the goods and services tax (GST)) in the Canadian data, there remains very few degrees of freedom to estimate model-based measures of core inflation. Though regime shifts are also problematic for those taking a statistical approach to the measure of core inflation, the problem is less severe. Explicit use of the disaggregated price data allows the researcher to use a wider range of data for the analysis. While the model-based approach is

theoretically appealing, it has these practical problems; in contrast, the statistical approach is likely to yield a stable measure of core inflation even through periods of rapid change.

5.2 What is the appropriate periodicity of the data for policy?

For most purposes, it would seem that core would necessarily be a smooth measure of inflation. This suggests that averages might be a simple approach that could resolve any of the problems with published inflation series. However, for the purpose of inflation as an indicator, there is a trade-off between identifying a growth trend, and identifying shifts in this trend in a timely manner. Long moving averages will impart smoothness, but at the cost of causing a phase shift that would mask shifts in the trend for some time. Though quite noisy, the timeliness of monthly data makes it an invaluable source of information on new developments that may hint at future trends in inflation.

The use of a core measure as an early-warning indicator has led some researchers to focus on short-term fluctuations in inflation in defining a core measure that takes full advantage of the timeliness of the data. For example, various U.S. researchers derive core measures based on monthly fluctuations (Bryan and Pike 1991; Bryan and Cecchetti 1993b), while Roger (1995, 1997) emphasizes measures based on quarterly changes in inflation for New Zealand. However, the volatility in monthly and quarterly data suggests that sole reliance on higher frequency data could lead to policy errors or unnecessary volatility in the instruments of monetary policy. Cecchetti (1996) reports that changing the growth calculation from a month-to-month to a quarter-over-quarter growth rate halves the noise in inflation. This is evident in Figure 1, which compares 1-month, 3-month, and 12-month moving averages of changes in the CPIxT. The moving average calculation reduces the standard deviation of the series from 0.25 for 1-month changes to 0.15 for a 3-month moving average, and then to 0.10 for a 12-month moving average.

Some of the noise in monthly inflation rates is inherent to the process of surveying prices and constructing a price index. Some prices are infrequently sampled and other prices are adjusted only occasionally. In particular, the prices of certain components are recorded by Statistics Canada only once or twice each year (property taxes and tuition fees, for example, are recorded only once each year). At that time, the monthly changes in these prices are exaggerated and would therefore tend to be excluded each year from month-to-month measures of core inflation. In some instances, fluctuations will represent an accumulation of moderate monthly changes that are reported only on an intermittent basis. Finally, there will also be prices that are modified only intermittently, perhaps because of the cost of price adjustment or regulation. Because they are discontinuous, these price variations can seem to be very strong compared with those that are more regular. In both cases, the elimination of these monthly variations could result in systematic underestimation of trend inflation. In fact, Taillon (1997b) has observed that the inflation rate established using the weighted median of monthly movements of the components was very often below the year-over-year change in the CPI.

Annual growth has important advantages if the core measure is to be used as a target. The smoothness of annual inflation rates enhances communication with the public. It is likely that an annual horizon or longer corresponds to the planning horizon of consumers and businesses negotiating and establishing changes in wages, pensions, loans, or other contracts that may take inflation into account. Year-over-year inflation rates help to pin down the longer-range inflation expectations of individuals and businesses.

For all of these reasons, core inflation measures in Canada are based on annual price changes. These core measures are described below.

5.3 Bias in price indexes

There may be systematic biases in published inflation rates. Research on bias, where the methodology used to generate the price index creates persistent measurement problems, is critical though distinct from the research on core inflation, and is not dealt with in this paper. (See Crawford, Fillion, and Laflèche (1998) for a detailed discussion of bias in the CPI.)

6. Measures of Underlying Inflation at the Bank of Canada

6.1 CPIxFET as a measure of core inflation

The term *core* CPI inflation at the Bank of Canada officially corresponds to the 12-month change in the CPI excluding food and energy and the effects of indirect taxes (CPIxFET), which is shown in Figure 2.

The choice of CPIxFET inflation as the *operational* target for policy reflects several considerations. First, CPIxFE is published independently by Statistics Canada and is widely used and familiar to the public; it is corrected for the effects of changes in indirect taxes using a pre-determined methodology documented in the *Bank of Canada Review* (1991). As such, CPIxFET is a publicly available measure of inflation outside the direct control of the central bank. Second, as a measure of core inflation, CPIxFET shares the same general trend as the CPI, but is much less volatile. Food and energy prices are notoriously more volatile than many other prices. These prices are determined in markets where supply shocks (unrelated to monetary policy) are very important, so that excluding these prices should produce a measure of inflation that is more controllable. While there can be persistent divergences in inflation rates, there has been no tendency for food and energy prices to rise at a systematically different rate than total CPI inflation for an extended period of time. Therefore, focusing on the CPIxFET is effectively the same as focusing on the trend in the CPI itself, with the advantage that uncertainty around the trend is reduced. Third, the definitional difference in the two measures of inflation is straightforward and this simplicity facilitates the communication of policy. This is important when CPIxFET deviates from the CPI and policy

decisions may require some explanation. It also aids in accountability, since the exclusion of volatile components emphasizes to the public that the Bank is concerned with the more persistent movements in inflation.

One disadvantage to this measure is that, in excluding a portion of the expenditure-weighted CPI basket, it deviates from a cost-of-living index. This can lead to criticism from the public, since they are concerned with changes in the cost of living. Secondly, it is unlikely that every price movement in food and energy represents a relative price shock. Work by Crawford, Fillion, and Laflèche (1998) shows that food purchased in restaurants, for example, is not a volatile price series and it may therefore be inappropriate to exclude it from a core measure. At the same time, in excluding only food and energy, it fails to consider relative price changes in other components that perhaps ought to be excluded (for example, tobacco or mortgage interest costs).

The effects of changes in indirect taxes are also excluded from CPIxFET. Price changes resulting from changes in indirect taxes represent one-time-only shifts in the price level. In Canada, large changes in indirect taxes included the introduction of the value-added tax in 1991 and a large decline in tobacco taxes in 1994. The size of these shocks illustrates the prudence of an approach that directly takes these changes into account. Note, however, that the calculation of CPIxFET relies on the somewhat ad hoc assumption that tax changes are passed through immediately and one-for-one to consumer prices.

6.2 Other measures of core inflation

Other measures of underlying inflation have been generated based on the statistical disaggregated approach and are currently used at the Bank of Canada. These measures, originally documented in Crawford, Fillion, and Laflèche (1998) and Laflèche (1997a, 1997b), are discussed in the following sections. To demonstrate the methodologies that are used to derive these measures of core inflation, numerical examples are presented in Appendix 1.

Although the current CPI contains 182 components at the most detailed level, a higher level of aggregation (54 components) allows us to retain the same number of components for the entire 1986 to 1998 observation period. It also represents a set of components for which consistent definitions in terms of coverage are available for the entire period. These 54 components and their corresponding 1996 basket weight in the CPI are shown in Appendix 2, Table A2.1 and Figure A2.1.[1]

All of the statistical measures were calculated after the year-over-year percentage changes in the 54 components of the total index had been adjusted for the effect of the GST coming into

1. This is not the weight applied to the year-over-year growth in each component, but the implicit weight; that is, the weight applied to the cumulative increase from the base.

force in January 1991.[2] It was necessary to make this adjustment beforehand, since the statistical measures cannot account for a phenomenon that has influenced most of the components in the index. On the other hand, the effects of specific indirect taxes that generate sharp fluctuations in certain components, such as the significant drop in tobacco taxes in February 1994, are automatically eliminated if they are sufficiently pronounced, so that they do not require any special treatment.

- ***Meantsd***

Meantsd is the weighted average of the cross-sectional distribution of price changes that has been trimmed to exclude values farther than 1.5 standard deviations from the average (see Figure 3). As such, it excludes the most volatile components at each *point in time*. As an example, Table 1 reports the components excluded from the meantsd measure of core inflation in August 1998.

This measure of inflation is roughly equivalent to one that trims the 5 per cent extreme in each tail of the distribution; however, it has the advantage that it allows the amount trimmed to be dependent on the tightness of the distribution in each period. The determination that any price change larger than 1.5 standard deviations represents an outlier is somewhat arbitrary. Interestingly, the same subcomponents are often excluded on both extremes of the distribution. In other words, extreme fluctuations tend to be reversed. This supports the interpretation that they represent temporary supply shocks.

One feature of this measure is that the coverage tends to vary from month to month. If annual price movements for a particular component vary such that the price change is always close to 1.5 standard deviations, then it may be included one month when it is just below 1.5 standard deviations and excluded the next when it is just above. As a result, meantsd is more volatile *over time* than most other measures of underlying inflation (see Tables 2 and 3). Moreover, the change in coverage makes it difficult to compare monthly reports of the 12-month changes in inflation.

Meantsd is not published by the Bank of Canada, but it is used in internal current analysis of evolving inflationary pressures. Every month, it is used in conjunction with information on which subcomponents are actually excluded (see Table 1 for an example). Thus, it is used as much to highlight the specifics of extreme price movements as it is to provide an underlying inflation rate.

- ***CPIX***

This measure of inflation is defined as the year-over-year growth in the CPI excluding the eight subindexes that have been most volatile, as well as indirect taxes (see Figure 4). The idea for CPIX originated with the observation that some elements of the aggregate food and energy subcomponents were not at all volatile. For example, food purchased in restaurants, dairy products, and bakery products were rarely excluded from meantsd. Eliminating these elements from the

2. The effect of the adoption of the GST in January 1991 was estimated for each of the 54 components, taking into account the proportion of taxable goods in each component and the effect of the elimination of the sales tax on manufactured products, to which most goods were subject prior to adoption of the GST.

basket, as is done in CPIxFET, might in fact exclude useful information on the trend in inflation. This suggested that it might be possible to have a measure of core inflation that was less volatile but included more of the basket.

CPIX makes the most of what we do know about the historical variability of disaggregated prices to determine which price changes ought not to be included in core inflation. To obtain the new index, CPIX, eight components are excluded from the total price index: fruits, vegetables, gasoline, natural gas, fuel oil, mortgage interest, intercity transportation, and tobacco products.

These eight components have been selected based on the frequency of their exclusion from calculation of the weighted averages of truncated distributions over the observation period. They were removed over 50 per cent of the time from a weighted average of the distribution truncated by 10 per cent on each side and over 25 per cent of the time from meantsd, the weighted average of the distribution where values that are above and below the average by at least 1.5 times the standard deviation are truncated.[3] In other words, the components that are most often among *the most volatile subcomponents at a point in time* are identified as candidates for exclusion. This calculation is made over the longest sample possible: November 1979 to November 1996 for most components and January 1986 to November 1996 for the exception.

The resulting core measure actually contains more of the basket than the Bank's official core inflation measure. Based on the 1996 basket weights, the CPIxFET excludes 26 per cent of the total CPI basket, whereas the CPIX excludes only 16 per cent. CPIX is also less volatile than CPIxFET, while the means are virtually identical. CPIX is published regularly in the *Bank of Canada Review.*

The exclusion of this particular set of prices is also appealing because of the source of their dynamics. Most of the prices are volatile owing to their particular market; for example, fruit, vegetables, gasoline, fuel oil, natural gas, and intercity transportation. Those items are affected by world prices and are sensitive to the exchange rate. Others, such as tobacco products and mortgage costs, are affected by government policy.

However, CPIX also has disadvantages. Selection of the components excluded from the total index could have been based on some other criterion (other than selection of the frequency of exclusion), and may depend on the observation period (that is, the exclusion frequency may vary according to the period considered). Finally, the systematic exclusion of certain components may result in loss of information about the basic price trend. These disadvantages are not any larger than they are for CPIxFET. They may in fact be less, since what is excluded is justified on economic grounds; exclusion is also more justifiable than for CPIW, for example, which is more dependent on the observation period.

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3. Appendix 1 presents a numerical example of the calculation of the distribution truncated by 10 per cent on each side.

- ***CPIW***

The choice to zero-weight particular components and recompute the aggregate index (as is done for CPIxFET, CPIX, and meantsd) is based on the assumption that all movements in these components correspond to either noise or one-time-only relative price shocks. At least on occasion, these movements may reflect changes in the inflation process. This will be an important exception from the perspective of the monetary authority. It may be useful to compute a measure that includes some effect from these large changes in prices rather than ignore these movements entirely. This is the notion behind CPIW (see Figure 5), which attenuates the influence of highly variable components. This measure has the advantage that it includes all elements of the initial basket. CPIW is published regularly in the *Bank of Canada Review.*

CPIW is computed by assigning each of the 54 components a weight inversely proportional to its variability.[4] In this way, instead of eliminating the most volatile components (which amounts to assigning them a zero weight), they are downweighted. This involves applying a second weight to each good and service in the CPI basket in addition to the initial weight, which represents the importance of the component in consumer spending. This second weight has been defined as the reciprocal of the standard deviation of the change in relative prices.[5] Therefore, the higher the standard deviation (that is, the larger the change in the relative price of a component), the lower the weighting. Appendix 1 presents a numerical example of a double-weighted measure. Table A4 in Appendix 1 compares the weights assigned in total CPI and in CPIW to the 10 components whose weights are most different in absolute value.

Compared with CPIX, CPIW has the advantage that no component is systematically excluded. There is, however, an arbitrary element in the construction of this series, since it is necessary to choose the period for which the standard deviation of the relative price change will be calculated. The reweighting procedure is also arbitrary.

- ***Wmedian***

The weighted median, shown in Figure 6, is an order statistic defined as the 50th percentile of the weighted cross-sectional distribution of price changes. As an order statistic, the weighted median will be a more robust measure of the tendency of the individual price changes that make up the distribution than the weighted mean if the distribution of price changes is non-normal. This measure is not used regularly at the Bank of Canada, but we include it in this analysis since there is some evidence that the distribution of price changes in Canada may be non-normal.[6] Conclusions

4. This idea was proposed by Scott Roger of the Reserve Bank of New Zealand.
5. Change in relative price is measured by the difference between the price change of a component and the inflation rate as measured by total CPI. The standard deviation is calculated for the period from January 1986 to April 1997.
6. Roger (1995, 1997, 2000), for example, argues for the use of a weighted median measure of core inflation. Appendix 3 includes a detailed discussion of the moments of the distributions of price changes in Canadian data.

are tentative because the skewness and kurtosis of the distributions vary with the horizon used to calculate the price changes. Furthermore, the moments of the distribution are changing over time.

The cross-sectional distribution of price changes appears to be leptokurtic. The results in Table A3.4 show that calculations based on the distribution of year-over-year changes indicate weighted kurtosis of 9.7 for the 1986–91 moderate inflation subperiod. Weighted kurtosis does decline to 6.1 for the 1992–98 sample, but this is far more than the kurtosis of 3 for a normal distribution. This suggests that eliminating extreme movements may be worthwhile. However, if the distribution is symmetric, trimming the tails and recalculating the weighted mean will not result in any change in the weighted mean. Hence, to determine whether the higher moments of the distribution suggest the use of a weighted median rather than the weighted mean, we look at the skewness in the distribution.

There is evidence of skewness in the distribution when price changes are calculated at some frequencies, though not for those calculated over an annual horizon, which is the one used in Canada to calculate measures of underlying inflation.[7] Weighted skewness in year-over-year price changes averages about 0.15 for the full sample. However, weighted skewness seems to have fallen along with the mean of inflation in recent years. Average weighted skewness fell from 0.3 in the 1986–91 period to zero in the 1992–98 period. Therefore, it does not appear that, on average, skewness is a particular problem in the Canadian data. However, the standard deviation surrounding the skewness for the full sample is 1.4, indicating that skewness presents a problem during particular periods (see Table A3.1). The possibility of skewness during particular episodes could support the use of the weighted median as a measure of core inflation.

7. An Evaluation of Various Measures of Underlying Inflation

To determine which of these measures of underlying inflation is best suited to policy purposes, policy-makers require a means of discriminating among them. Any evaluation is complicated by the fact that there are no formal criteria by which the accuracy of a core inflation measure can be assessed. Since core measures are to be tools for policy, it is reasonable to assess them based on their suitability to those proposed uses. Hence, we begin with a discussion of the attributes that would make different measures suitable as an indicator of current and future trends in inflation, or as a target for monetary policy.

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7. The weighted mean consistently below the weighted median is visual evidence of the skewness in the distribution; see Harnett and Murphy (1993). This is shown, for example, in Figure A3.5, for the case of the 36-month change in prices, whereas it is not the case for frequencies at or below 12-month changes (Figures A3.1–A3.3).

7.1 As a good indicator of current and future trends in inflation

As an indicator of current and future trends in inflation, the ideal core inflation would be a smooth measure that closely approximates the general trend in inflation. Furthermore, it would have some forecasting ability for the trend. In other words, the excluded portion would reflect transitory movements in inflation. As such, it would be independent of the future trend in inflation. Timeliness is also an important attribute if core inflation is used as a guide for policy. However, all of the core inflation measures are available at the same time, so we do not evaluate these measures based on this last criteria.

7.1.1 Does the core measure capture the persistent movements or is it still volatile?

Table 2 lists the mean and standard deviation of each of the various core measures, as well as the CPI. In terms of variability, defined as the standard deviation divided by the mean, each of the core measures has lower variability than the CPI. However, there is very little to differentiate the various core measures. The mean over the full sample ranges from 2.76 for the weighted median to 2.90 for both CPIW and meantsd. Measures of variability range from a low of 0.42 for CPIX, the least variable measure, to 0.51 for the weighted median.

Table 3 reports the same statistics for the period 1992m1 to 1998m8, to evaluate whether the core measures continue to perform well in the recent low and stable inflation period. The mean has declined for each of these measures and the CPI. The mean of the core inflation measures now ranges from 1.52 for the weighted median to a high of 1.87 for CPIX inflation. The higher mean for the CPIX reflects the exclusion of mortgage costs, which have been declining due to low interest rates. The standard deviation has also fallen sharply, ranging from 0.43 for the meantsd to a low of 0.30 for CPIW. For most of the core measures, variability is about half of the 0.50 calculated for the CPI, with the lowest variability of 0.18 reported for both CPIW and CPIX.

Close review of the individual prices that make up aggregate inflation suggests that a regime change to a period of low and stable inflation may be reflected in a wide variety of prices. Almost all of the disaggregated prices in the CPI have lower means and standard deviations in the period after 1992 than in the earlier period (see Table A2.1).

As suggested by Cecchetti (1996), a longer-run two-sided moving average of inflation will provide us with a fairly good benchmark of the trend in inflation. We use this benchmark to assess the various core measures.[8] Figure 7 graphs the weighted mean of the CPI changes and its two-sided 36-month moving average (both are adjusted to remove the effects of the GST in 1991 and the

8. This measure of the underlying trend in inflation is not useful for conducting monetary policy because of the two-year phase shift (or lag). It is, however, quite useful as a means of calculating the order of magnitude of the transitory component in inflation ex post.

tobacco tax shock of 1994, to remove misleading shifts).[9] Table 4 reports the root mean square error and mean absolute deviations, to compare how close each core measure captures the benchmark trend. It appears that the CPIW more closely approximates the persistent movements in the 36-month moving average than the alternative measures.

This approach assumes that the trend changes gradually. As previously noted, the trend in Canadian inflation appears to have changed abruptly in 1992. Therefore, we conduct a similar analysis for the low inflation period beginning in 1992. The results appear to be robust to a change in the sample period (see Table 5).

7.1.2 Does the core measure help predict future trends in inflation?

To assess whether the core measure has any indicator properties for the future trend in inflation, we review the simple correlations between each core measure and the CPIxT (CPI excluding indirect taxes) at various future intervals: 6 months, 12 months, 18 months, and 24 months (see Tables 6 and 7).[10] We report correlations between the core measures and the CPIxT, rather than the CPI itself, to abstract from the large indirect tax shocks in the data. The importance of indirect tax shocks is evident when comparing the CPI and the CPIxT at all samples. At 6 months ahead, the correlation between the CPI and the CPIxT is only 0.65, despite a 6-month overlap in the data.

Table 6 shows the correlations over the full 1986 to 1998 sample period. These correlations are quite high. They suggest that core measures do contain information about future movements in inflation. CPIX outperforms the other measures: at 24 months ahead, the correlation between CPIX and CPIxT is 0.75.

The high correlations may partly reflect the fact that there is a shift in the trend of all of the core measures at the same time in 1992. To investigate this possibility, we look at the correlations for the 1986–90 subperiod (see Table 8). The correlations have fallen somewhat, but these measures do contain some information about the future movements in inflation. Table 9 reports the same correlations over the 1992–98 sample, when inflation was low and stable. For that period, the correlations are still lower. At 6 and 12 months ahead, CPIxT is negatively correlated with most of the core inflation measures. The exception is the CPIxFET, which is slightly positively correlated

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9. There are also small differences in the weighted mean and Statistics Canada's official measure of CPI inflation, arising from the fact that we use the original official basket weights in each period to calculate the weight of the component in the weighted mean, whereas CPI inflation uses implicit weights, which change each month. These implicit weights represent expenditures shares using the original quantities and prices that have been updated from the base period. The difference between implicit and official basket weights becomes most important just before the basket weights are revised, as the original weights become outdated (see Statistics Canada 1995 for a more technical explanation of the weights).

10. Note that contemporaneous correlations and those 6 months ahead will include some overlap between the core measure and CPIxT, since these are 12-month averages.

6 months ahead (during the period of overlap) and uncorrelated 12 months ahead. At 18 months ahead, correlations change sign and are all positive. At this lead, CPIxFET is the most highly correlated at 0.44 and CPIX the next highest at 0.40. This pattern of correlations through time suggests that many of the shocks excluded from the core measures but included in the CPIxT have been eliminated between 12 and 18 months ahead. The core measures are still notably correlated with the CPIxT at 18 and 24 months ahead, suggesting that they do have useful information on the future trend in inflation. The highest correlation at 24 months is between CPIxT and CPIW; it is reported at 0.42.

Ultimately, if monetary policy was successful in perfectly targeting inflation, correlations would fall to zero (see Rowe and Yetman 2000). It is important therefore to look at more than just simple correlations in the data.

7.1.3 Results of simple indicator models

To determine whether the different measures of core inflation contain information that can improve simple autoregressive forecasts of total CPI, we estimate equations of the following form:[11]

$$\pi_t^{CPI} = \alpha_0 + \alpha_1 \pi^{CPI}_{t-12} + \alpha_2 \pi^{core}_{t-1}$$

where π_t^{CPI} is the year-over-year percentage change of total CPI and π_t^{core} is a measure of core inflation.[12] As indicated by the $\bar{R}^2$, the results (Table 9) indicate that each measure adds some information to that provided by the simple autoregressive model. The highest $\bar{R}^2$ are obtained when CPIW and CPIX are added to the autoregressive model.

To differentiate between CPIW and the change in CPIX, we added these two variables to the equation at the same time. The significance level of the CPIW coefficient then proved to be slightly higher than that of the change in CPIX, although neither of the two coefficients was significant at the standard level of 95 per cent.

7.1.4 Properties of excluded components

One can check whether the portion of the CPI excluded from a core measure has similar attributes to noise or reversible price shocks. For the CPIX we evaluated each of the eight subcomponents that have been eliminated from this measure to see whether they contain information on the trend in inflation. Figure 8 graphs the difference between the CPI and each of the different measures of underlying inflation. These gaps are the excluded portions of each of the core measures, and

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11. These results were originally reported in Laflèche (1997b), and are therefore calculated on a shorter sample period than other results.
12. Each of the series, including the CPI, has been corrected for the effects of the introduction of the GST.

therefore should represent temporary movements in inflation around its trend. The gaps could be interpreted as measures of relative price shocks.

We next test whether core inflation and the excluded portion are independent. To do so, we do a variation of Cogley (1998) and test whether the excluded portion over- or underpredicts the transient component of the CPI.[13] This is implemented with an OLS regression.

We do the following OLS regression, where π_t is CPI inflation at time t, and π_{t+h} is CPI inflation at time $t+h$. In each regression, h equals 6, 12, and 18, respectively. π_t^{core} is the core measure and u_t is the random error term:

$$(\pi_{t+h} - \pi_t) = \alpha + \beta(\pi_t^{core} - \pi_t) + u_t$$ [14]

If $\alpha = 0$ and $\beta = 1$, the excluded component is an unbiased predictor of the transitory component of inflation.[15] If β is less than one, then it understates the transitory movements; if it is greater than one, then it overstates the movements. This experiment captures the extent to which transient movements are subsequently reversed.

The regressions over the full 1986m1 to 1998m8 sample provide some interesting results.[16] Six months ahead (Table 10), CPIW provides the most encouraging result, since we cannot reject the restriction that $\alpha = 0$ and $\beta = 1$ for any of the core measures (except CPIX), suggesting that what has been excluded from these measures reflects transitory movements. At this horizon, CPIX seems to underpredict the transient movements in the CPI.

However, at 12 and 18 months ahead, the test results are reversed (see Tables 11 and 12). The CPIX clearly performs much better at capturing transitory movements that are reversed over these longer horizons, since the freely estimated coefficient β is very close to one. The joint restriction that $\alpha = 0$ and $\beta = 1$ cannot be rejected for CPIX and meantsd at either the 12- or 18-month horizon, nor can it be rejected for CPIxFET at the 18-month horizon. Overall, these results support a few measures of inflation. In particular, CPIW and CPIX appear to be useful measures of core inflation, though over different horizons.

Next, we re-estimate the regressions to investigate whether these conclusions hold up for the low and stable inflation period of 1992m1 to 1998m8 (see Tables 13–15). Six months ahead, all measures do well. CPIW still fares best at this horizon, since it is still the case $\beta = 1$ even without

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13. These regressions are quite similar to those included in Crawford, Fillion, and Laflèche (1998) $\pi_{t+h} = f(\pi_t, \pi_t^{core})$, and their finding that the sum of the coefficients was close to one.
14. Standard errors have been corrected using the Hansen and Hodrick (1980) adjustment, where appropriate.
15. The simpler restriction that $\beta = 1$ leads to identical conclusions in each of the regressions.
16. Samples identified in Tables 9–14 are shorter than the full sample, since the sample is adjusted as required to allow for $t+h$ period ahead observations.

a restriction. We cannot reject the joint restriction that $\alpha = 0$ and $\beta = 1$ for any of the core measures except CPIX. These results suggest that what has been excluded by these measures accurately captures the transitory movements in the CPI at this horizon. As in the regressions over the full sample, CPIX seems to underpredict the transient movements in the CPI at the 6-month-ahead horizon.

At the longer horizons of 12 and 18 months, all of the measures overstate the variable portion of the CPI (see Tables 14 and 15). The joint restriction is easily rejected by the data in each of the regressions and the estimated coefficients are well above one. This may reflect the fact that there is much less variability in the CPI over this period (except for the temporary decline in inflation due to the tobacco tax cut in 1994). In these regressions, $\beta > 1$ can also mean that relative prices of excluded components are I(0) rather than I(1) and start reversing after 12 months. This is expected of food prices (crop failures affect the price level in the crop year only), and can be a feature of oil prices as well.

7.1.5 Robustness

Both CPIX and CPIW use data on the historical volatility of the components to derive measures of underlying inflation. This approach is based on the assumption that the past will be representative of the future. To evaluate this assumption, we investigate the recent period.

In deriving the CPIX, the standard deviation of the individual components of the CPI could have been used to determine which components are volatile instead of the components that were most frequently eliminated by meantsd or a 10 per cent limited information estimator. Table A2.1 lists the means and standard deviations of 54 individual components of the CPI. Over the full sample period, the eight components excluded from CPIX are among those with the highest standard deviations.

Interestingly, while the means and standard deviations of most of the subcomponents have fallen dramatically, the same subset of eight still represents some of the most volatile components. Table A2.1 reports the means and standard deviations for two major subperiods, 1986 to 1991, and the low inflation period of 1992 to 1998. The Spearman rank correlation coefficient between the two periods is 0.63, suggesting that the relative volatility of the various components in the first period is indicative of that in the recent low and stable inflation period. This supports the choice of CPIX in that it will likely perform out-of-sample. It also indicates that using constant weights based on an earlier period to reweight the components, as in CPIW, is not a bad approximation.

Tables A2.2–A2.4 report the frequency with which these components were eliminated from meantsd over the full sample and over two different subperiods: 1986m1 to 1998m8; 1992m1 to 1998m8; and 1996m12 to 1998m8. The columns in Tables A2.2–A2.4 report each component, the number of times it was excluded from meantsd, and the percentage of time it was excluded. The

eight components excluded from CPIX have been marked with shaded rows. In Table A2.3, for example, the first row indicates that education prices were eliminated by the meantsd procedure 44 times, or 55 per cent of the time. In each of the 1986–98 and 1992–98 periods, the eight components removed from CPIX were among the nine subindexes thrown out most often, owing to their location over 1.5 standard deviations from the weighted mean. The ninth most frequently discarded subindex is education, which is also the one with the largest mean of any component (7.5 per cent). This is not surprising, given the large hikes in university tuition fees in recent years resulting from cutbacks to government funding. However, the education price subindex does not have a particularly high standard deviation. This would suggest that although education prices are discarded by the criteria for meantsd, they may not belong among those components excluded from CPIX on the basis of their volatility, since they are not really volatile, merely persistently high. In the very short but recent 1996–98 period, there is some change in what might be excluded from CPIX. Fruit and tobacco prices, for example, are less likely to be in the tails of the distribution of price changes, although the other six components originally excluded would still be selected for exclusion about half of the time.

7.2 As a target for monetary policy

This assessment has focused on the properties required for these measures to be a good indicator of current and future trends in inflation. As an official operational or direct target, however, the core measure would be a public measure; therefore, it would require a few other attributes, as follows:

- the core measures should not exclude too much of the consumer basket, since it could then deviate too much from a cost of living index if the excluded portion followed a different trend than the overall index;
- the methodology used to extract core inflation from public inflation rates should not change frequently or be viewed by the public as being obscure or under the control of the monetary authority itself;
- it should be clear that the monetary authority has some capacity to realize the target given the monetary policy instrument.

Many of these considerations underlie the use of the CPIxFET inflation as the operational target in Canada. CPIxFET could be considered the direct target, since the attributes that make it a useful operational target also make it a suitable direct target. It is the best-understood of all measures of core inflation and its direct use would further clarify the fact that policy affects only the underlying trend in inflation. CPIX inflation might also make a suitable target, since it is less variable than CPIxFET and at the same time includes more of the original CPI basket than CPIxFET. Of course, some education of the public would be required if CPIX were adopted as a target, since it is not as well understood by the public as the CPI or CPIxFET.

8. Conclusion

The notion of a causal link between monetary policy and the underlying trend in inflation, illustrated through our standard model of the transmission mechanism, motivates research on measures of core inflation. As a measure of the general trend in inflation, core inflation is useful for policy-makers as an indicator of current and future trends in inflation, or as a target for monetary policy.

The Bank of Canada monitors several measures of core or underlying inflation on a regular basis. Each of the measures is based on the disaggregated approach to measuring core inflation. Furthermore, they are all based on 12-month price changes, for several reasons. First, 12-month price changes provide an important smoothing aspect to the data. Second, for movements in year-over-year growth in the CPI, there is no evidence of excess skewness or kurtosis. Third, some price changes are infrequently sampled while other prices only change occasionally or annually (such as tuition fees). These infrequent price changes can be gradually included in the inflation rate. Fourth, by construction, year-over-year growth rates avoid the problem of regular seasonality. Finally, it is reasonable to think that contracts, pensions, and other economic planning that takes inflation into account would largely be based on a somewhat longer horizon, such as an annual one.

The range of measures considered in this report includes one that excludes the most volatile components historically (CPIX); one that includes all elements of the basket, but downweights their influence on the aggregate inflation rate based on their volatility (CPIW); one that reflects the 50th percentile (wmedian); one that excludes the most volatile components at a point in time (meantsd); and one that excludes prices traditionally considered to be affected by temporary supply shocks (CPIxFET). Each of these measures has some attributes of a core measure. However, the environment of low and stable inflation in Canada makes it difficult to differentiate between them, since the variability of all the measures is quite low. Most results seem to suggest the CPIW is best at capturing the trend in inflation, while other criteria suggest that CPIX is the most useful measure.

Interestingly, the sharp drops in the means and standard deviations of the various core measures and the aggregate CPI are mirrored in the disaggregated data. The low-inflation environment is evident in almost all disaggregated prices, at least to some extent. A review of their relative means and standard deviations suggests that if we recalculated the eight most volatile components to determine which to exclude based solely on recent data, we would choose the same eight that were excluded historically from CPIX: fruit, vegetables, gasoline, fuel oil, natural gas, intercity transportation, mortgage interest costs, and tobacco products. The exclusion of these eight components is easily motivated on economic grounds. The first six of these subindexes contain prices that are sensitive to temporary shocks affecting global food and energy prices and to the exchange rate, while the last two are heavily influenced by central bank or government policy. This suggests that the items excluded from CPIX are robust to the sample period.

Along with the decline in the means and standard deviations of inflation, we report a decline in the skewness and kurtosis of the cross-sectional distribution of inflation. Although it appears that weighted skewness is not a problem on average, the level of kurtosis and the standard deviation of skewness suggests that the distribution of price changes is non-normal during specific episodes, particularly during the introduction of the GST, which created a huge change in relative prices—adding 7 per cent to services and subtracting from many goods. This suggests that the weighted median is worth considering as a robust measure of underlying inflation.

Comparisons of the various measures of underlying inflation suggest that different measures do well along different dimensions. Each measure of core provides some particular insight into how inflation is evolving. Therefore, rather than selecting one measure as the best to perform the role of core inflation as an indicator of the trend in inflation, it might be more useful to have a limited number of measures of underlying inflation and use the varied information in each of them to create a more accurate picture of the dynamics in inflation. Since it is impossible to measure trend inflation with precision, it is wise to have a set of estimates on hand. When those estimates all convey the same message, it is reasonable to consider them to be a reliable guide for the conduct of monetary policy. On the other hand, if the estimates were to diverge, it would be necessary to closely examine the reasons for that divergence, to ensure that monetary policy is appropriately oriented. At present, Bank staff regularly monitor four measures of core inflation: CPIxFET, CPIX, CPIW, and meantsd. Differences in these measures assist in identifying the source of the shock. For example, CPIX has a higher mean over recent years because it excludes mortgage interest costs that have been declining as a result of low interest rates. Staff also regularly identify the items that are eliminated from meantsd to isolate the components that are most volatile in each month. This approach would be most useful in periods of change when the core inflation measures diverge, since it would raise a warning signal to investigate further.

It may be interesting to pursue alternative avenues of research in the future. To date, work on model-based measures of core inflation has been hampered by changes in the inflation process in the 1990s. However, once low and stable inflation persists for some time, a model-based approach could yield some interesting insights. The evidence of the usefulness of various core measures described in this report would be strengthened by comparison with the very different alternative measures that are produced by a model-based approach.

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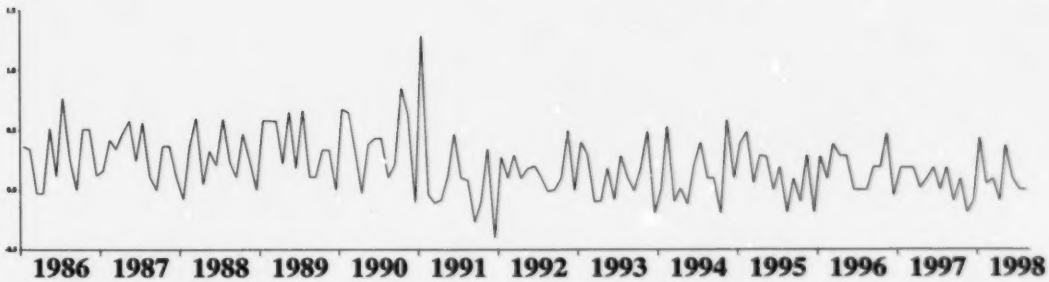
Figure 1: A comparison of different frequencies for price changes

Growth in CPIxT, monthly
1986m1 to 1998m8; standard deviation is 0.25



Growth in 3-month moving average of CPIxT, monthly
1986m1 to 1998m8; standard deviation is 0.15

Growth in 12-month moving average of CPIxT, monthly
1986m1 to 1998m8; standard deviation is 0.10

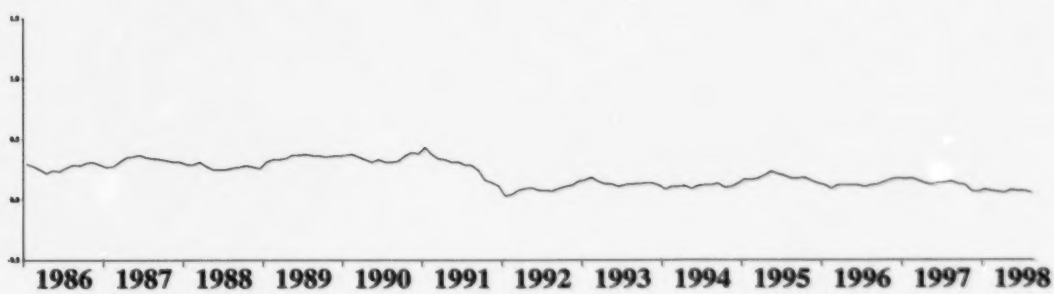


Figure 2: Year-over-year growth of CPIxFET and year-over-year growth in CPIxT

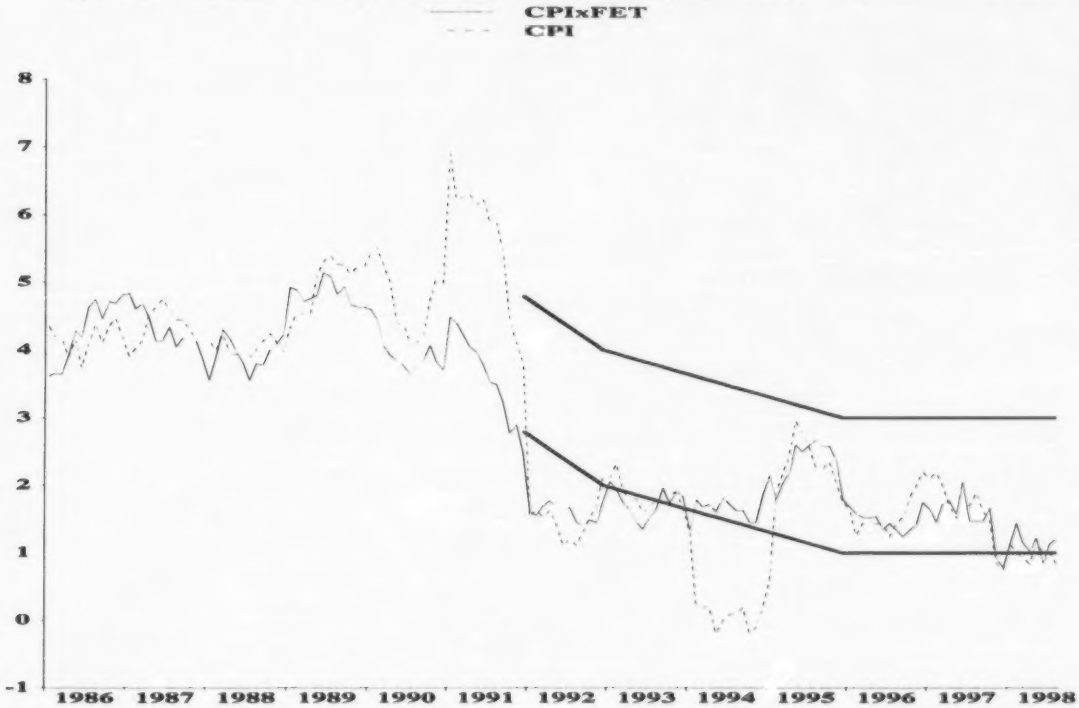


Figure 3: Meantsd and year-over-year growth in CPIxT

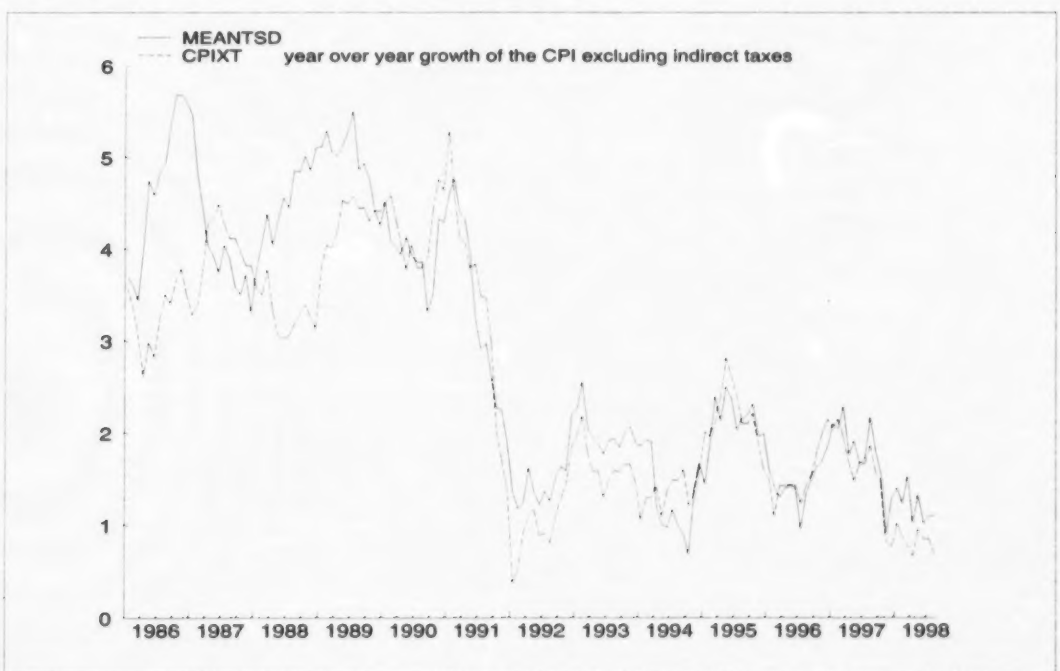


Figure 4: Year-over-year growth of CPIX and year-over-year growth in CPIxT

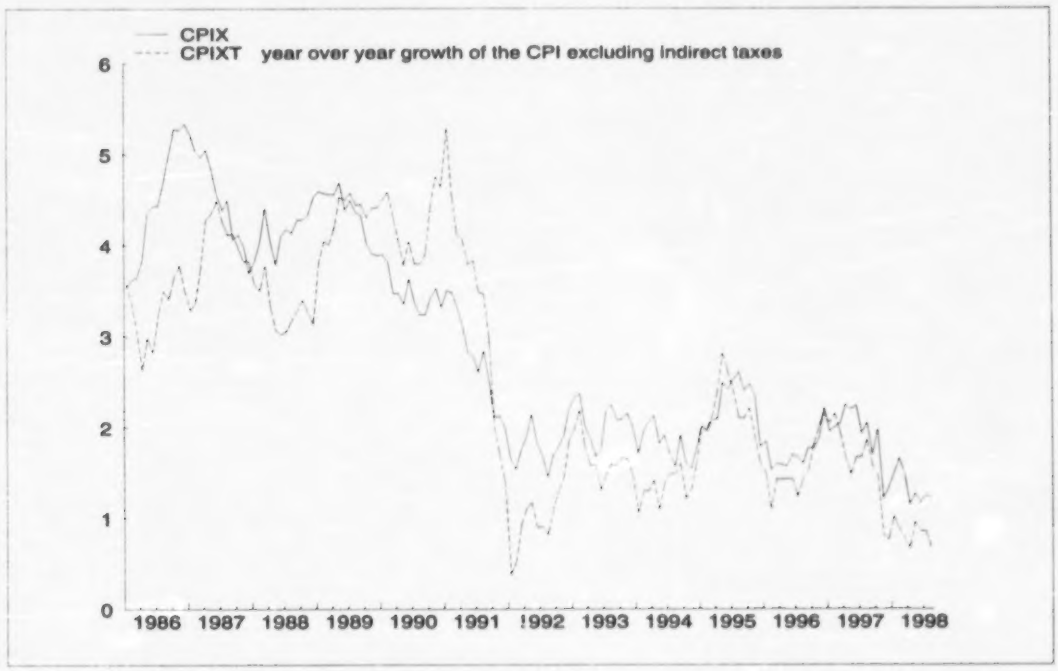


Figure 5: CPIW and year-over-year growth in CPIxT

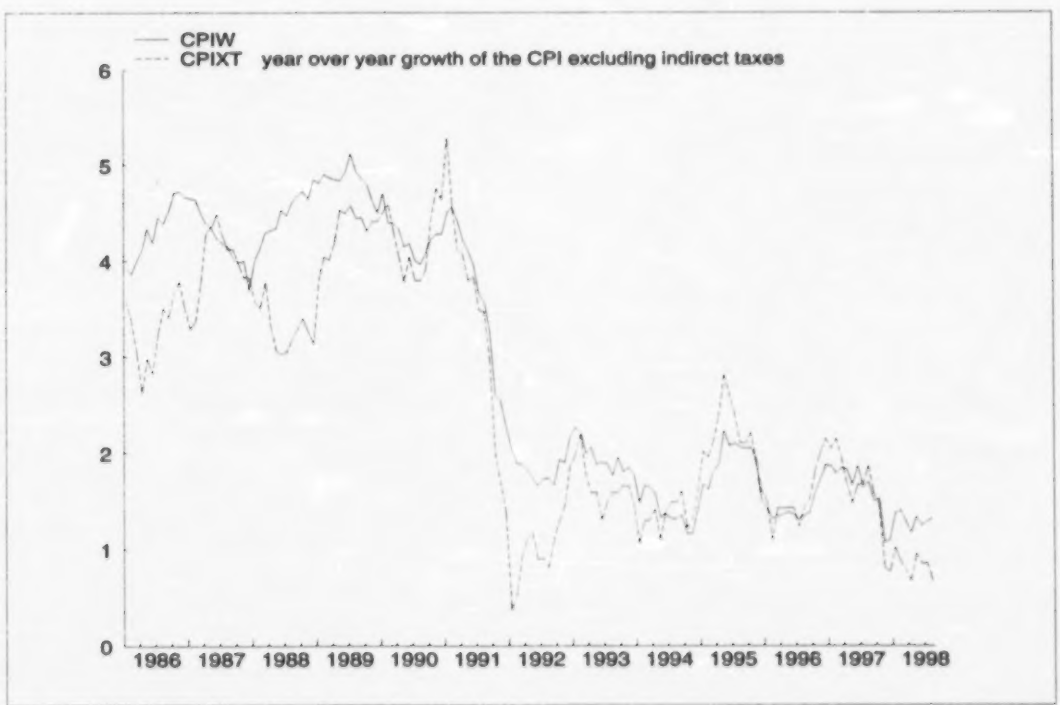


Figure 6: WMEDIAN and year-over-year growth in CPIxT: 1986m1 to 1998m8

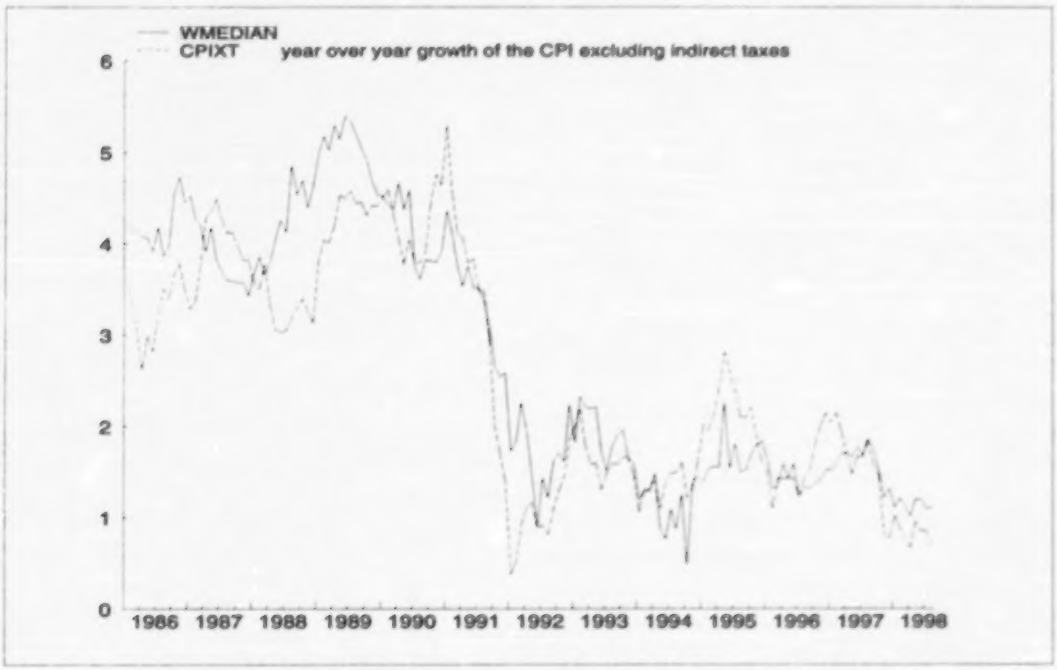


Figure 7: Moving average of weighted mean: 1986m1 to 1998m8

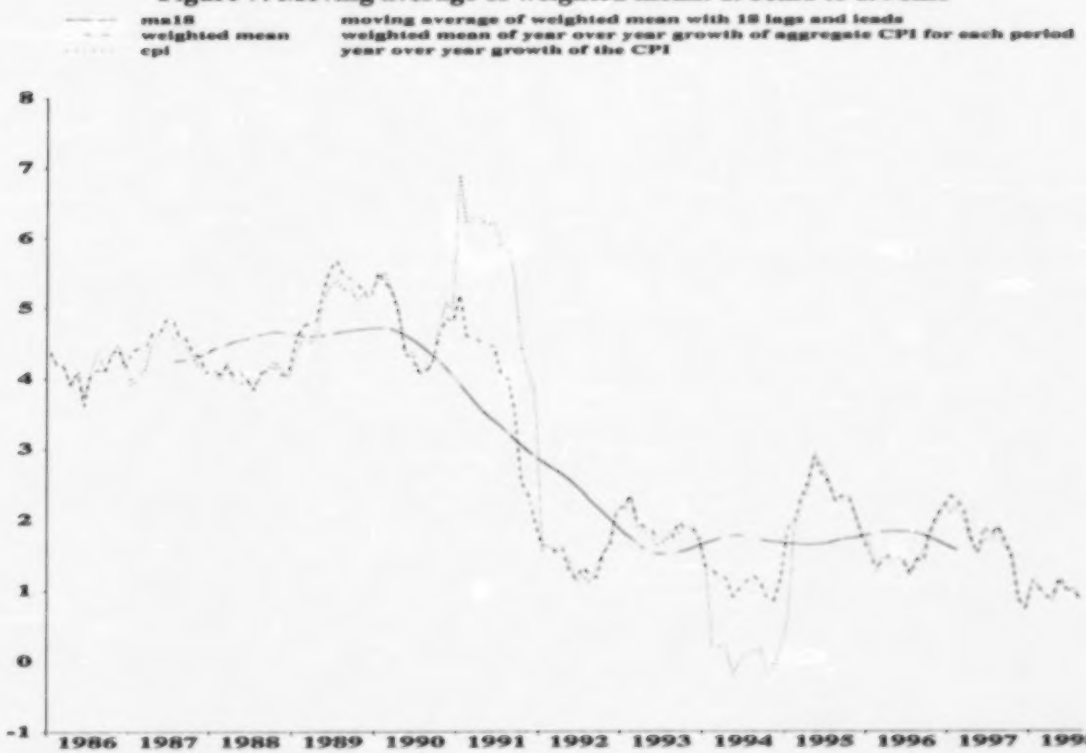
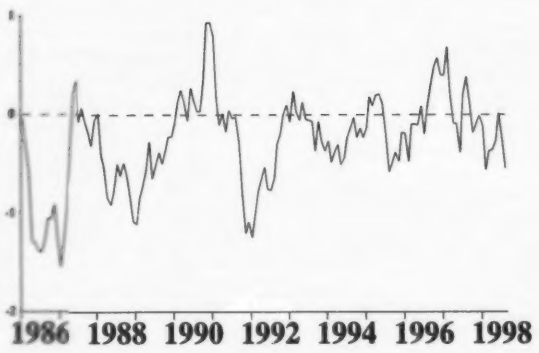


Figure 8:

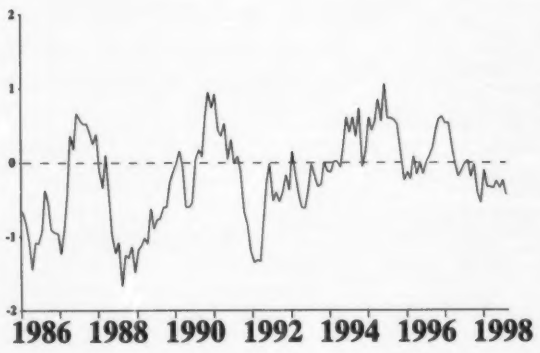
CPI excluding indirect taxes minus core measure

sample 86:1 to 98:8

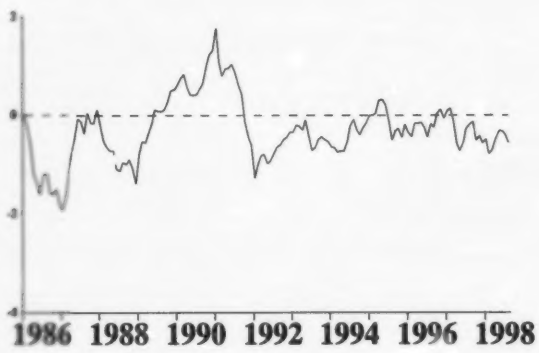
(CPIxT-CPIXFET)



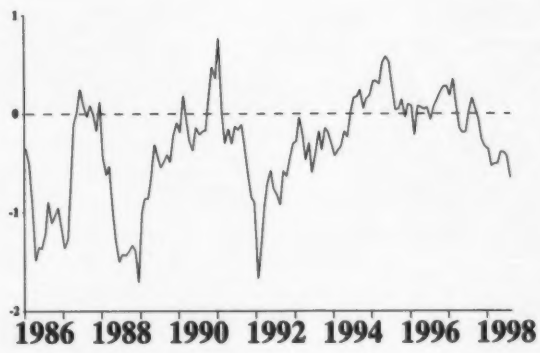
(CPIxT-WMEDIAN)



(CPIxT-CPIX)



(CPIxT-CPIW)



(CPIxT-MEANTSD)

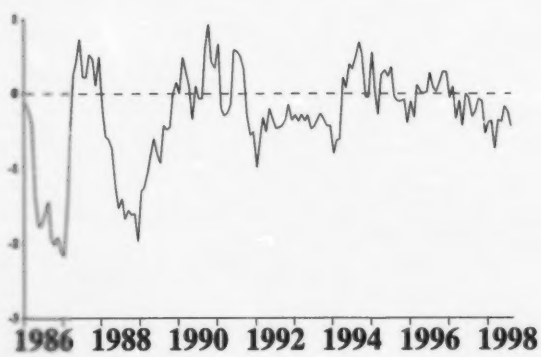


Table 1: Components excluded from meantsd in August 1998

Component	Growth over 12 months
Natural gas	10.9%
Fuel oil and other fuels	-10.0%
Gasoline	-11.9%
Intercity transportation	6.7%
Travel services	7.0%
Tobacco products	6.6%

Table 2: Core inflation measures: 1986m1 to 1998m8

	mean	standard deviation	variability (stddev/mean)
Δ CPI	2.96	1.77	0.60
Δ CPIxFET	2.84	1.34	0.47
wmedian	2.76	1.41	0.51
Δ CPIX	2.86	1.20	0.42
CPIW	2.90	1.40	0.48
meantsd	2.90	1.44	0.50

Δ denotes the 12-month growth rate

Table 3: Core inflation measures: 1992m1 to 1998m8

	mean	standard deviation	variability (stddev/mean)
Δ CPI	1.43	0.72	0.50
Δ CPIxFET	1.66	0.39	0.24
wmedian	1.52	0.36	0.24
Δ CPIX	1.87	0.34	0.18
CPIW	1.66	0.30	0.18
meantsd	1.64	0.43	0.26

Table 4: Root mean squared error and mean absolute deviation 1987m7 to 1997m2

Core	RMSE	MAD
Δ wmean	0.64	0.56
Δ CPIxFET	0.50	0.40
wmedian	0.51	0.42
Δ CPIX	0.57	0.47
CPIW	0.40	0.34
meantsd	0.61	0.52

Table 5: Root mean squared error and mean absolute deviation 1993m6 to 1997m2

Core	RMSE[a]	MAD[b]
Δ wmean	0.56	0.50
Δ CPIxFET	0.43	0.33
wmedian	0.43	0.33
Δ CPIX	0.43	0.35
CPIW	0.35	0.32
meantsd	0.49	0.44

[a] Root mean squared error: $RMSE = \sqrt{\left(\frac{1}{n}\right)\sum_{i=1}^{n}(core_t - ma_t)^2}$

[b] Mean absolute deviation: $MAD = \left(\frac{1}{n}\right)\sum_{i=1}^{n}|core_i - ma_i|$

Table 6: Correlation of core measures with future CPIxT inflation 1986m1 to 1998m8

	Δ CPIxT[t]	Δ CPIxT[t+6]	Δ CPIxT[t+12]	Δ CPIxT[t+18]	Δ CPIxT[t+24]
Δ CPI	0.92	0.65	0.46	0.49	0.40
Δ CPIxFET	0.93	0.84	0.74	0.71	0.61
wmedian	0.90	0.85	0.75	0.70	0.60
Δ CPIX	0.86	0.85	0.79	0.77	0.75
CPIW	0.93	0.85	0.74	0.70	0.62
meantsd	0.89	0.85	0.73	0.70	0.64

Table 7: Correlation of core measures with future CPIxT inflation 1986m1 to 1990m12

	Δ CPIxT[t]	Δ CPIxT[t+6]	Δ CPIxT[t+12]	Δ CPIxT[t+18]	Δ CPIxT[t+24]
Δ CPI	0.87	0.29	-0.07	-0.05	-0.44
Δ CPIxFET	0.34	0.33	0.29	0.29	0.14
wmedian	0.22	0.59	0.45	0.28	0.00
Δ CPIX	-0.12	0.13	0.23	0.40	0.57
CPIW	0.19	0.52	0.44	0.30	0.13
meantsd	-0.09	0.44	0.42	0.27	0.20

Table 8: Correlation of core measures with future CPIxT inflation 1992m1 to 1998m8

	Δ CPIxT[t]	Δ CPIxT[t+6]	Δ CPIxT[t+12]	Δ CPIxT[t+18]	Δ CPIxT[t+24]
Δ CPI	0.61	-0.21	-0.62	0.02	0.12
Δ CPIxFET	0.72	0.11	-0.05	0.44	0.17
wmedian	0.43	-0.22	-0.46	0.10	0.29
Δ CPIX	0.79	-0.09	-0.34	0.40	0.31
CPIW	0.57	-0.14	-0.44	0.22	0.42
meantsd	0.75	-0.10	-0.56	0.24	0.39

Table 9: Regression results 1986m1 to 1997m4

π_t^{core} [a]	α_0	α_1	α_2	$\bar{R}^2$	S.D.
ΔCPI	0.85 (1.67)[b]	0.67 (3.97)		0.43	1.20
ΔCPIxFET	-0.40 (-0.79)	-0.29 (-0.98)	1.36 (3.37)	0.58	1.03
wmedian	-0.00 (-0.01)	-0.55 (-1.77)	1.51 (5.03)	0.64	0.96
ΔCPIX	-0.71 (-1.08)	-0.10 (-0.36)	1.28 (2.91)	0.66	0.93
CPIW	-0.52 (-0.88)	-0.84 (-2.65)	1.90 (4.86)	0.66	0.93
meantsd	0.04 (0.09)	-0.13 (-0.46)	1.04 (3.46)	0.59	1.02

[a] The Hansen and Hodrick correction has been used to correct for overlapping data.

[b] Student t-statistics are in parentheses

Table 10: Regressions: six months ahead 1986m1 to 1998m2

ΔCPI[t+6]	**ΔCPIxFET**	**wmedian**	**ΔCPIX**	**CPIW**	**meantsd**
$\bar{R}^2$	0.35	0.40	0.29	0.45	0.39
α	-0.02 (0.10)	0.06 (0.35)	-0.06 (0.31)	-0.06 (0.31)	-0.06 (0.30)
β	0.82 (3.35)	0.90 (4.36)	0.56 (2.68)	1.01 (4.93)	0.80 (3.52)
p-value H_0: (β=1, α=0)	0.75	0.86	0.07	0.95	0.62

Table 11: Regressions: twelve months ahead 1986m1 to 1997m8

ΔCPI[t+12]	**ΔCPIxFET**	**wmedian**	**ΔCPIX**	**CPIW**	**meantsd**
$\bar{R}^2$	0.58	0.63	0.50	0.67	0.49
α	-0.06 (0.42)	0.10 (0.69)	-0.12 (0.79)	-0.13 (1.00)	-0.14 (0.85)
β	1.48 (8.31)	1.59 (10.87)	1.03 (6.41)	1.71 (10.81)	1.25 (6.29)
p-value H_0: (β=1, α=0)	0.02	0.00	0.73	0.00	0.37

Table 12: Regressions: eighteen months ahead 1986m1 to 1997m2

ΔCPI[t+18]	ΔCPIxFET	wmedian	ΔCPIX	CPIW	meantsd
$\bar{R}^2$	0.55	0.55	0.52	0.54	0.45
α	-0.19 (2.22)	-0.06 (0.61)	-0.23 (2.55)	-0.27 (2.98)	-0.26 (2.63)
β	1.39 (13.07)	1.42 (13.71)	1.01 (11.75)	1.49 (13.64)	1.16 (10.10)
p-value H_0: (β=1, α=0)	0.00	0.00	0.03	0.00	0.02

Table 13: Regressions: six months ahead 1992m1 to 1998m2

ΔCPI[t+6]	ΔCPIxFET	wmedian	ΔCPIX	CPIW	meantsd
$\bar{R}^2$	0.29	0.29	0.26	0.32	0.20
α	-0.23 (1.25)	-0.12 (0.55)	-0.41 (3.22)	-0.26 (1.37)	-0.23 (1.19)
β	0.81 (3.91)	0.96 (6.57)	0.82 (4.08)	1.00 (5.80)	0.90 (1.94)
p-value H_0: (β=1, α=0)	0.44	0.79	0.36	0.98	0.48

Table 14: Regressions: twelve months ahead 1992m1 to 1997m8

ΔCPI[t+12]	ΔCPIxFET	wmedian	ΔCPIX	CPIW	meantsd
$\bar{R}^2$	0.70	0.50	0.64	0.64	0.41
α	-0.48 (2.98)	-0.20 (1.13)	-0.83 (4.28)	-0.49 (2.76)	-0.43 (2.08)
β	1.63 (11.60)	1.67 (7.13)	1.67 (11.99)	1.85 (10.25)	1.70 (5.21)
p-value H_0: (β=1, α=0)	0.00	0.00	0.00	0.00	0.03

Table 15: Regressions: eighteen months ahead 1992m1 to 1997m2

ΔCPI[t+18]	ΔCPIxFET	wmedian	ΔCPIX	CPIW	meantsd
$\bar{R}^2$	0.66	0.34	0.60	0.46	0.44
α	-0.47 (4.83)	-0.20 (1.67)	-0.73 (6.11)	-0.43 (3.66)	-0.42 (3.55)
β	1.36 (14.55)	1.17 (7.33)	1.37 (16.91)	1.34 (12.06)	1.49 (11.15)
p-value H_0: (β=1, α=0)	0.00	0.14	0.00	0.00	0.00

Appendix 1: Numerical Examples Demonstrating Core Measure Calculations

This appendix shows numerical examples of how various measures of underlying inflation are calculated. Table A1 lists some sample data. Table A2 lists the inflation rate that would be calculated with this data and each of these methods outlined in the text below.

Table A1: Sample data

	Sample data					
Ordered sample	1.00	1.50	2.00	3.50	3.50	5.00
Corresponding weights in consumer basket	0.05	0.30	0.20	0.20	0.15	0.10
Cumulative weights	0.05	0.35	0.55	0.75	0.90	1.00

- ***Weighted average***

This is the sum of the year-over-year price changes for items in the sample (line 1 of Table A1) multiplied by their respective weights (line 2):

1.00 x 0.05 + 1.50 x 0.30 + ... + 5.00 x 0.10 = 2.63.

Note that other core measures such as CPIX and CPIxFET are also calculated in this way after certain components have been eliminated through a zero weighting.

More precisely, if each x_i is a price change associated with a weight $w_i \geq 0$, such that the $\sum_{i=1}^{n} w_i$ is the total weight of the n components included in the core measure, then the weighted average is:

$$\overline{\pi}_{it} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} = \frac{w_1 x_1 + w_2 x_2 + w_3 x_3 + \ldots + w_n x_n}{w_1 + w_2 + w_3 + \ldots + w_n}$$

- ***Median (presented for comparison with the weighted median)***

This is the central item of the ordered sample (odd number of items) or the average of the two central items (even number of items). Here, we have:

(2.00 + 3.50)/2 = 2.75.

- ***Weighted median (Wmedian is computed in a similar manner)***

This is the value that separates the ordered sample into two parts, with the sum of the weights of each part being equal to 50 per cent. Here, the weighting reaches 50 per cent between the values 1.50 and 2.00. The weighted median is equal to:

2.00 - (2.00-1.50) x (55-50)/ (55-35) = 1.88.

- ***Weighted average of distribution truncated by 10 per cent on each side***

This methodology was one of two used to identify the most volatile components of the aggregate CPI index to exclude from CPIX.

The smallest value of the sample in Table A1 is eliminated, but since its weight is only 5 per cent, the next value, 1.50, must also be eliminated in part; its weight thus changes from 30 per cent to 25 per cent. The largest value in the sample, 5.00, is also eliminated. In this way, 10 per cent has been truncated from each side of the distribution. This gives a new weighted average of (1.50 x 0.25 + 2.00 x 0.20 + 3.50 x 0.20 + 3.50 x 0.15) = 2.00, which is normalized by dividing it by the sum of the remaining weights: 2.00/0.80 = 2.50.

Table A2: Results

	Sample data
Weighted average	2.63
Median	2.75
Weighted median	1.88
Weighted average of distribution truncated by 10 per cent on each side	2.50

- ***Double-weighted measure (CPIW)***

In Table A3, we return to the example in Table A1, and assume that the standard deviation is the same for the first five items (i.e., 2.0), but twice as large for the last one. Since this last item is more volatile than the others, its weight should be reduced and the value of the new weighted average should be smaller than that of the old one, as this item is the one with the largest price change.

Table A3: Additional sample data for calculation of double-weighted measure

	Sample data					
(1) Ordered sample	1.00	1.50	2.00	3.50	3.50	5.00
(2) Corresponding weights	0.05	0.30	0.20	0.20	0.15	0.10
(3) Standard deviation	2.00	2.00	2.00	2.00	2.00	4.00
(4) 1/standard deviation	0.50	0.50	0.50	0.50	0.50	0.25
(5) Double weight: (2) x (4)	0.025	0.150	0.100	0.100	0.075	0.025
(6) Normalization: (5) / 0.475	0.053	0.316	0.211	0.211	0.158	0.053

To obtain the new weights, the initial weights (line 2) are multiplied by the reciprocal of standard deviations (line 4), then normalized (by dividing the result obtained by the sum of the double weights, which is equal to 0.475) so that their sum is equal to 1. Comparing the new weights

with the initial weights, the weight of the last item is reduced by about half (its standard deviation being twice as high as that of the other items), while that of each of the first five items has increased slightly.

In this case, the new weighted average, 1.00 x 0.053 + 1.50 x 0.316 + ... + 5.00 x 0.053 = 2.50, is smaller than the one calculated with the conventional weights, which was equal to 2.63.

For example, the double-weighted measure of core inflation, known as CPIW, is computed as follows:

$$\pi_t^{CPIW} = \sum_{i=1}^{n} \pi_{it} \bullet dwt_{it}$$

where dwt_{it} is the double weight, computed as the product of the time-varying published weights for the components and the inverse of the standard deviation of the difference between the year-over-year inflation rate for each component and the total CPI. These weights are normalized so that they sum to one:[17]

$$dwt_{it} = \left(\frac{\left[w_{i,t} \bullet \frac{1}{\sigma_i} \right]}{\left[\sum_{i=1}^{n} w_{i,t} \bullet \frac{1}{\sigma_i} \right]} \right)$$ where σ_i is the standard deviation, and

σ_i is calculated for the period between January 1986 and April 1997 as:

$$\sigma_i = \left[\left(\frac{1}{n-1} \right) \sum [(\pi_{it} - \pi_t^{CPI}) - \overline{(\pi_{it} - \pi_t^{CPI})}]^2 \right]^{\frac{1}{2}}$$

where π_{it} represents the weighted mean of the year-over-year change in a particular component of the CPI, and π_t^{CPI} is the year-over-year change in the published CPI.

Table A4 lists the components whose weights changed the most (in absolute value) in moving from total CPI to CPIW. It also shows the extent to which the component weights can be modified as a function of the variability of their relative prices. The change in relative price is measured by the difference between the price change of the component and that of the total CPI. For example, the weight of the component whose relative price change is lowest (standard deviation of 0.85), "Food purchased from restaurants," rises from 5.40 per cent to 13.23 per cent, a difference of 7.83 percentage points. Its weight is 2.5 times higher in CPIW than in the total CPI. On the other hand, the weight of the component whose relative price change is highest (standard deviation of 16.32), "tobacco products and smokers' supplies," drops from 1.63 per cent to 0.21 per cent, a

17. Note that the weights are time-varying owing to revisions in basket weights.

difference of 1.42 percentage points. Its weight in CPIW amounts to no more than about one-eighth of that assigned in the total CPI.

The components listed in Table A4 are not necessarily those whose relative prices are the most volatile. For example, the relative price of "vegetable and vegetable preparations," which is not included in the table, is much more volatile than the price of "other food products" (standard deviation of 9.31 versus 3.39). However, the weight given to "vegetables and vegetable preparations" in the CPI is smaller than that of "other food products" (1.06 versus 2.70). Therefore, the difference, in absolute terms, between the weights of the first component in the CPI and in CPIW is smaller than that of the second component.

Table A4: Components whose weights have changed most in CPIW (in absolute value)

Component	(1) Weight in CPI	(2) Weight in CPIW	(3) Difference (2) - (1)	(4)[a] Standard Deviation of Difference	Ratio (2)/(1)
Food purchased from restaurants	5.40	13.23	7.83	0.85	2.5
Rented accommodation	7.18	14.65	7.47	1.02	2.0
Clothing	4.16	5.55	1.39	1.56	1.3
Purchase of automotive vehicles	7.47	4.15	-3.22	3.64	0.6
Mortgage interest cost	5.33	2.36	-2.97	4.68	0.4
Gasoline	3.81	0.86	-2.95	9.14	0.2
Property replacement cost	3.29	1.23	-2.06	5.54	0.4
Tobacco products & smokers' supplies	1.63	0.21	-1.42	16.32	0.1
Meat	3.04	1.73	-1.31	3.65	0.6
Other food products[b]	2.70	1.65	-1.05	3.39	0.6

[a] The standard deviation is calculated for the period between January 1986 and April 1997.

[b] Residual item of the food category of our 54-component set. The food category includes the following items: meat; fish and other seafood; dairy products and eggs; bakery and other cereal products; fruits, fruit preparations, and nuts; vegetables and vegetable preparations; food purchased from restaurants; and other food products.

Appendix 2: An Investigation of the Subcomponents of the CPI

Figure A2.1

Weights of the 54 subcomponents of the CPI
(1996 basket at January 1998 prices)

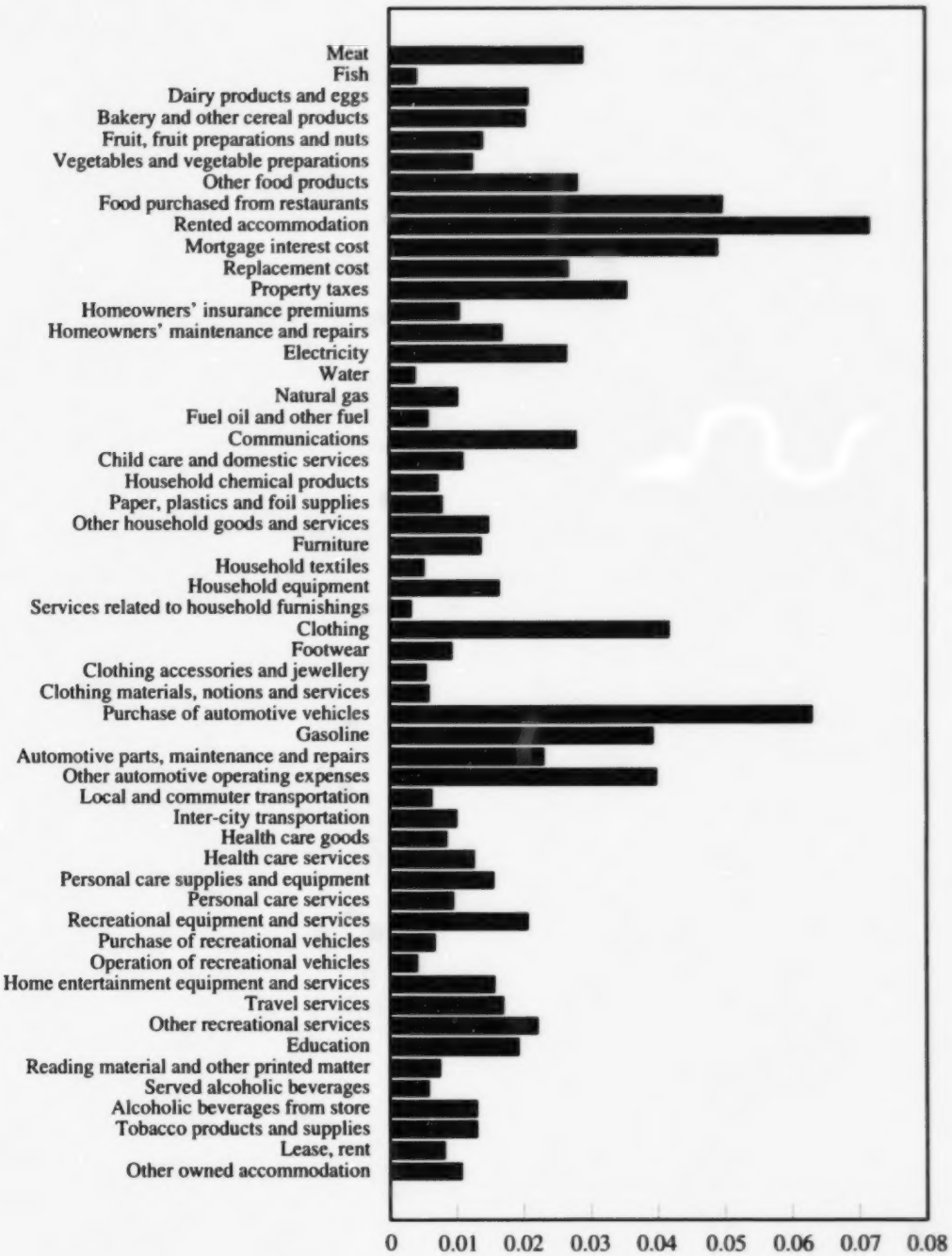


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Table A2.1: Year-over-year growth of the 54 subcomponents of the CPI

		Full sample 86m1 to 98m8		Subsample 86m1 to 91m12		Subsample 92m1 to 98m8	
Component	1996 Wt.	Mean	Std. Dev[a]	Mean	Std. Dev	Mean	Std. Dev
Meat	0.0290	2.64	3.85	4.20	4.47	1.21	2.48
Fish	0.0041	3.24	3.61	4.74	3.94	1.88	2.64
Dairy products and eggs	0.0208	2.10	1.61	2.84	1.29	1.44	1.59
Bakery and other cereal products	0.0204	2.71	1.69	3.32	1.46	2.16	1.70
Fruit, fruit preparations and nuts	0.0140	1.26	5.23	3.96	5.23	-1.17	3.89
Vegetables and veg. preparations	0.0125	2.56	9.64	4.68	10.08	0.65	8.85
Other food products	0.0282	1.72	3.00	2.24	2.61	1.25	3.26
Food purchased from restaurants	0.0498	3.06	1.57	4.60	0.74	1.67	0.37
Rented accommodation	0.0717	2.78	1.31	4.02	0.59	1.67	0.57
Mortgage interest cost	0.0491	0.94	6.02	5.42	5.04	-3.10	3.41
Replacement cost	0.0268	3.12	5.58	6.26	6.75	0.29	1.22
Property taxes	0.0355	4.78	2.59	6.61	1.05	3.14	2.46
Homeowners' insurance prems.	0.0105	4.09	4.96	6.52	6.06	1.91	1.93
Homeowners' maint. & repairs	0.0169	1.65	2.56	2.83	1.55	0.59	2.83
Electricity	0.0265	3.42	2.47	4.87	1.63	2.10	2.37
Water	0.0039	5.14	2.73	6.12	3.04	4.25	2.06
Natural gas	0.0102	0.78	5.46	-1.68	3.45	3.00	5.97
Fuel oil and other fuel	0.0058	0.55	11.49	0.68	15.24	0.43	6.61
Communications	0.0279	0.88	2.62	-0.68	2.29	2.28	2.06
Child care and domestic services	0.0110	4.37	2.02	5.87	1.23	3.02	1.60
Household chemical products	0.0073	1.51	2.76	3.58	1.44	-0.36	2.31
Paper, plastics and foil supplies	0.0079	2.88	4.73	3.56	2.46	2.26	6.05
Other household goods&serv.	0.0148	2.78	2.36	4.99	1.03	0.78	1.09
Furniture	0.0137	1.82	1.99	3.17	1.62	0.60	1.44
Household textiles	0.0052	1.55	2.65	3.22	2.13	0.05	2.12
Household equipment	0.0164	1.08	1.69	2.17	1.64	0.10	0.98
Services rel. to hh furnishings	0.0033	3.26	1.73	4.51	1.10	2.13	1.39
Clothing	0.0417	2.01	1.83	3.45	1.38	0.72	1.07
Footwear	0.0093	1.85	1.93	3.30	1.32	0.53	1.37
Clothing accs. & jewellery	0.0055	1.40	2.50	3.37	1.44	-0.38	1.83
Clothing mat., notions and ser.	0.0059	2.92	1.57	4.42	0.60	1.58	0.72
Purchase of automotive vehicles	0.0630	3.96	2.75	3.77	3.33	4.12	2.10
Gasoline	0.0393	0.89	9.07	1.88	11.81	-0.01	5.51
Auto. parts, maint. & repairs	0.0230	2.05	2.17	3.68	1.94	0.58	1.01

Table A2.1: Year-over-year growth of the 54 subcomponents of the CPI

		Full sample 86m1 to 98m8		Subsample 86m1 to 91m12		Subsample 92m1 to 98m8	
Component	1996 Wt.	Mean	Std. Dev[a]	Mean	Std. Dev	Mean	Std. Dev
Other auto operating expenses	0.0398	6.32	2.67	7.42	2.21	5.32	2.68
Local & commuter transport.	0.0063	5.45	2.88	6.60	1.58	4.41	3.36
Inter-city transportation	0.0100	6.58	8.90	6.99	11.73	6.21	5.23
Health care goods	0.0085	3.98	3.69	7.29	2.46	0.99	1.25
Heath care services	0.0126	3.43	1.47	4.63	0.42	2.35	1.20
Personal care supplies & equip.	0.0155	1.53	2.04	2.71	1.32	0.46	2.00
Personal care services	0.0095	3.79	1.97	5.53	1.16	2.23	0.99
Recreational equip.& services	0.0206	0.45	2.94	2.81	2.02	-1.66	1.81
Purchase of recreational vehicles	0.0067	4.11	2.22	4.67	2.80	3.60	1.34
Operation of recreational vehicles	0.0041	3.41	3.37	5.54	3.56	1.49	1.55
Home entertain. equip. & services	0.0156	-0.55	1.98	0.35	1.90	-1.35	1.68
Travel services	0.0169	3.48	3.67	3.93	2.93	3.08	4.20
Other recreational services	0.0220	5.09	1.97	6.68	1.42	3.65	1.09
Education	0.0192	7.48	2.83	7.45	3.61	7.51	1.91
Reading mat. & oth. print. matter	0.0075	4.50	2.31	6.04	1.35	3.11	2.11
Served alcoholic beverages	0.0058	3.96	3.05	6.82	1.78	1.39	0.86
Alcoholic beverages from store	0.0130	3.97	2.55	6.02	1.73	2.12	1.55
Tobacco products & supplies	0.0130	8.91	11.17	16.35	9.82	2.21	7.49
Lease rent	0.0082	2.48	5.09	3.47	4.95	1.59	5.09
Other owned accommodation	0.0107	3.42	3.12	6.14	2.15	0.96	1.23
All-items CPI	1.0000	2.96	1.77	4.66	0.73	1.43	0.72

[a] This is the standard deviation of the inflation rate for the individual component.

Table A2.1: Year-over-year growth of the 54 subcomponents of the CPI

		Full sample 86m1 to 98m8		Subsample 86m1 to 91m12		Subsample 92m1 to 98m8	
Component	1996 Wt.	Mean	Std. Dev[a]	Mean	Std. Dev	Mean	Std. Dev
Meat	0.0290	2.64	3.85	4.20	4.47	1.21	2.48
Fish	0.0041	3.24	3.61	4.74	3.94	1.88	2.64
Dairy products and eggs	0.0208	2.10	1.61	2.84	1.29	1.44	1.59
Bakery and other cereal products	0.0204	2.71	1.69	3.32	1.46	2.16	1.70
Fruit, fruit preparations and nuts	0.0140	1.26	5.23	3.96	5.23	-1.17	3.89
Vegetables and veg. preparations	0.0125	2.56	9.64	4.68	10.08	0.65	8.85
Other food products	0.0282	1.72	3.00	2.24	2.61	1.25	3.26
Food purchased from restaurants	0.0498	3.06	1.57	4.60	0.74	1.67	0.37
Rented accommodation	0.0717	2.78	1.31	4.02	0.59	1.67	0.57
Mortgage interest cost	0.0491	0.94	6.02	5.42	5.04	-3.10	3.41
Replacement cost	0.0268	3.12	5.58	6.26	6.75	0.29	1.22
Property taxes	0.0355	4.78	2.59	6.61	1.05	3.14	2.46
Homeowners' insurance prems.	0.0105	4.09	4.96	6.52	6.06	1.91	1.93
Homeowners' maint. & repairs	0.0169	1.65	2.56	2.83	1.55	0.59	2.83
Electricity	0.0265	3.42	2.47	4.87	1.63	2.10	2.37
Water	0.0039	5.14	2.73	6.12	3.04	4.25	2.06
Natural gas	0.0102	0.78	5.46	-1.68	3.45	3.00	5.97
Fuel oil and other fuel	0.0058	0.55	11.49	0.68	15.24	0.43	6.61
Communications	0.0279	0.88	2.62	-0.68	2.29	2.28	2.06
Child care and domestic services	0.0110	4.37	2.02	5.87	1.23	3.02	1.60
Household chemical products	0.0073	1.51	2.76	3.58	1.44	-0.36	2.31
Paper, plastics and foil supplies	0.0079	2.88	4.73	3.56	2.46	2.26	6.05
Other household goods&serv.	0.0148	2.78	2.36	4.99	1.03	0.78	1.09
Furniture	0.0137	1.82	1.99	3.17	1.62	0.60	1.44
Household textiles	0.0052	1.55	2.65	3.22	2.13	0.05	2.12
Household equipment	0.0164	1.08	1.69	2.17	1.64	0.10	0.98
Services rel. to hh furnishings	0.0033	3.26	1.73	4.51	1.10	2.13	1.39
Clothing	0.0417	2.01	1.83	3.45	1.38	0.72	1.07
Footwear	0.0093	1.85	1.93	3.30	1.32	0.53	1.37
Clothing accs. & jewellery	0.0055	1.40	2.50	3.37	1.44	-0.38	1.83
Clothing mat., notions and ser.	0.0059	2.92	1.57	4.42	0.60	1.58	0.72
Purchase of automotive vehicles	0.0630	3.96	2.75	3.77	3.33	4.12	2.10
Gasoline	0.0393	0.89	9.07	1.88	11.81	-0.01	5.51
Auto. parts, maint. & repairs	0.0230	2.05	2.17	3.68	1.94	0.58	1.01

Table A2.1: Year-over-year growth of the 54 subcomponents of the CPI

		Full sample 86m1 to 98m8		Subsample 86m1 to 91m12		Subsample 92m1 to 98m8	
Component	1996 Wt.	Mean	Std. Dev[a]	Mean	Std. Dev	Mean	Std. Dev
Other auto operating expenses	0.0398	6.32	2.67	7.42	2.21	5.32	2.68
Local & commuter transport.	0.0063	5.45	2.88	6.60	1.58	4.41	3.36
Inter-city transportation	0.0100	6.58	8.90	6.99	11.73	6.21	5.23
Health care goods	0.0085	3.98	3.69	7.29	2.46	0.99	1.25
Heath care services	0.0126	3.43	1.47	4.63	0.42	2.35	1.20
Personal care supplies & equip.	0.0155	1.53	2.04	2.71	1.32	0.46	2.00
Personal care services	0.0095	3.79	1.97	5.53	1.16	2.23	0.99
Recreational equip.& services	0.0206	0.45	2.94	2.81	2.02	-1.66	1.81
Purchase of recreational vehicles	0.0067	4.11	2.22	4.67	2.80	3.60	1.34
Operation of recreational vehicles	0.0041	3.41	3.37	5.54	3.56	1.49	1.55
Home entertain. equip. & services	0.0156	-0.55	1.98	0.35	1.90	-1.35	1.68
Travel services	0.0169	3.48	3.67	3.93	2.93	3.08	4.20
Other recreational services	0.0220	5.09	1.97	6.68	1.42	3.65	1.09
Education	0.0192	7.48	2.83	7.45	3.61	7.51	1.91
Reading mat. & oth. print. matter	0.0075	4.50	2.31	6.04	1.35	3.11	2.11
Served alcoholic beverages	0.0058	3.96	3.05	6.82	1.78	1.39	0.86
Alcoholic beverages from store	0.0130	3.97	2.55	6.02	1.73	2.12	1.55
Tobacco products & supplies	0.0130	8.91	11.17	16.35	9.82	2.21	7.49
Lease rent	0.0082	2.48	5.09	3.47	4.95	1.59	5.09
Other owned accommodation	0.0107	3.42	3.12	6.14	2.15	0.96	1.23
All-items CPI	1.0000	2.96	1.77	4.66	0.73	1.43	0.72

[a] This is the standard deviation of the inflation rate for the individual component.

Table A2.2: Frequency of elimination of the CPI components in the calculation of meantsd (1986m1 to 1998m8)

Component	meantsd	
	#	%
Vegetables and vegetable preparations	76	50
Inter-city transportation	74	49
Natural gas	72	47
Fuel oil and other fuel	70	46
Gasoline	69	45
Education	54	36
Tobacco products and smokers' supplies	53	35
Mortgage interest cost	51	34
Fruit, fruit preparation, and nuts	38	25
Rental and leasing of automotive vehicles	27	18
Communications	26	17
Replacement cost	26	17
Homeowners' insurance premiums	24	16
Recreational equipment and services	17	11
Other automotive vehicle operating expenses	17	11
Fish and other seafood	17	11
Local and commuter transportation	16	11
Travel services	16	11
Paper, plastics, and foil supplies	15	10
Water	14	9
Home-entertainment equipment and services	13	9
Health-care goods	12	8
Property taxes	12	8
Other food products	9	6
Homeowners' maintenance and repairs	7	5
Reading material and other printed matter	7	5
Household textiles	6	4
Clothing accessories and jewellery	5	3
Personal-care supplies and equipment	5	3
Meat	4	3
Other recreational services	3	2
Electricity	2	1
Household chemical products	2	1
Child care and domestic services	2	1
Operation of recreational vehicles	2	1
Other owned accommodation expenses	1	0
Furniture	1	0
Footwear	1	0
Purchase of recreational vehicles	1	0
Served alcoholic beverages	1	0

Table A2.3: Frequency of elimination of the CPI components in the calculation of meantsd (1992m1 to 1998m8)

Component	meantsd	
	#	%
Education	44	55
Mortgage interest cost	36	45
Vegetables and vegetable preparation	35	44
Natural gas	34	43
Inter-city transportation	30	38
Gasoline	24	30
Fuel oil and other fuel	24	30
Tobacco products and smokers' supplies	22	28
Fruit, fruit preparations and nuts	21	26
Rental and leasing of automotive vehicles	18	23
Recreational equipment and services	17	21
Travel services	16	20
Other automotive vehicles operating expenses	16	20
Local and commuter transportation	16	20
Paper, plastics, and foil supplies	15	19
Water	12	15
Property taxes	12	15
Home-entertainment equipment and services	10	13
Other food products	8	10
Homeowners' maintenance and repairs	7	9
Fish and other seafood	7	9
Reading material and other printed matter	7	9
Household textiles	5	6
Clothing accessories and jewellery	5	6
Personal-care supplies and equipment	5	6
Electricity	2	3
Communications	2	3
Child care and domestic services	2	3
Household chemical products	2	3
Homeowner's insurance premium	1	1
Furniture	1	1
Footwear	1	1
Purchase of recreational vehicles	1	1
Other recreational services	1	1

Table A2.2: Frequency of elimination of the CPI components in the calculation of meantsd (1986m1 to 1998m8)

Component	meantsd	
	#	%
Vegetables and vegetable preparations	76	50
Inter-city transportation	74	49
Natural gas	72	47
Fuel oil and other fuel	70	46
Gasoline	69	45
Education	54	36
Tobacco products and smokers' supplies	53	35
Mortgage interest cost	51	34
Fruit, fruit preparation, and nuts	38	25
Rental and leasing of automotive vehicles	27	18
Communications	26	17
Replacement cost	26	17
Homeowners' insurance premiums	24	16
Recreational equipment and services	17	11
Other automotive vehicle operating expenses	17	11
Fish and other seafood	17	11
Local and commuter transportation	16	11
Travel services	16	11
Paper, plastics, and foil supplies	15	10
Water	14	9
Home-entertainment equipment and services	13	9
Health-care goods	12	8
Property taxes	12	8
Other food products	9	6
Homeowners' maintenance and repairs	7	5
Reading material and other printed matter	7	5
Household textiles	6	4
Clothing accessories and jewellery	5	3
Personal-care supplies and equipment	5	3
Meat	4	3
Other recreational services	3	2
Electricity	2	1
Household chemical products	2	1
Child care and domestic services	2	1
Operation of recreational vehicles	2	1
Other owned accommodation expenses	1	0
Furniture	1	0
Footwear	1	0
Purchase of recreational vehicles	1	0
Served alcoholic beverages	1	0

Table A2.3: Frequency of elimination of the CPI components in the calculation of meantsd (1992m1 to 1998m8)

Component	meantsd	
	#	%
Education	44	55
Mortgage interest cost	36	45
Vegetables and vegetable preparation	35	44
Natural gas	34	43
Inter-city transportation	30	38
Gasoline	24	30
Fuel oil and other fuel	24	30
Tobacco products and smokers' supplies	22	28
Fruit, fruit preparations and nuts	21	26
Rental and leasing of automotive vehicles	18	23
Recreational equipment and services	17	21
Travel services	16	20
Other automotive vehicles operating expenses	16	20
Local and commuter transportation	16	20
Paper, plastics, and foil supplies	15	19
Water	12	15
Property taxes	12	15
Home-entertainment equipment and services	10	13
Other food products	8	10
Homeowners' maintenance and repairs	7	9
Fish and other seafood	7	9
Reading material and other printed matter	7	9
Household textiles	5	6
Clothing accessories and jewellery	5	6
Personal-care supplies and equipment	5	6
Electricity	2	3
Communications	2	3
Child care and domestic services	2	3
Household chemical products	2	3
Homeowner's insurance premium	1	1
Furniture	1	1
Footwear	1	1
Purchase of recreational vehicles	1	1
Other recreational services	1	1

Table A2.4: Frequency of elimination of the CPI components in the calculation of meantsd (1996m12 to 1998m8)

Components	meantsd	
	#	%
Fuel oil and other fuel	19	91
Inter-city transportation	19	91
Mortgage interest cost	18	86
Education	17	81
Natural gas	14	67
Gasoline	13	62
Vegetables and vegetable preparations	10	48
Home entertainment equipment and services	8	38
Other automotive vehicle operating expenses	7	33
Travel services	6	29
Tobacco	5	24
Fruit, fruit preparations and nuts	2	10
Communications	1	5
Clothing accessories and jewellery	1	5
Rental and leasing of automotive vehicles	1	5

Table A2.4: Frequency of elimination of the CPI components in the calculation of meantsd (1996m12 to 1998m8)

Components	meantsd	
	#	%
Fuel oil and other fuel	19	91
Inter-city transportation	19	91
Mortgage interest cost	18	86
Education	17	81
Natural gas	14	67
Gasoline	13	62
Vegetables and vegetable preparations	10	48
Home entertainment equipment and services	8	38
Other automotive vehicle operating expenses	7	33
Travel services	6	29
Tobacco	5	24
Fruit, fruit preparations and nuts	2	10
Communications	1	5
Clothing accessories and jewellery	1	5
Rental and leasing of automotive vehicles	1	5

Appendix 3: An Investigation of the Skewness and Kurtosis

The moments of the distribution of price changes have implications for the methodology to measure core inflation. Bryan and Cecchetti (1993b, 1996) and Bryan, Cecchetti, and Wiggins II (1997) offer evidence that the population of monthly price changes is characterized by skewness and kurtosis in the United States. Roger (1997) offers similar evidence for New Zealand. This skewness and kurtosis suggests the choice of an order statistic, such as the weighted median, as a robust and efficient estimator of the central tendency in prices. In this appendix, we report the skewness and kurtosis of the distribution of price changes for the Canadian CPI. Not surprisingly, we find that the price change distributions for Canada are characterized by skewness and kurtosis. However, the extent of the skewness and kurtosis depends on the horizon used to calculate the price change.

Tables A3.1–A3.4 provide summary statistics on the skewness and kurtosis in the Canadian data. To show how these calculations are made, we take the year-over-year case as an example. For each month from 1986m1 to 1998m8, we create a cross-sectional distribution of the 12th-month price changes of each of 54 subindexes of the CPI.[18] Then, we calculate the skewness and kurtosis of each of the monthly distributions. As suggested by Roger (2000), these statistics take into account the implicit weights that were actually used each month in the calculation of the CPI.[19] The resulting measures of weighted skewness and weighted kurtosis are listed in Table A3.1. Figures A3.1 to A3.5 illustrate the time series of the skewness and kurtosis coefficients graphically. Although the discussion in this appendix focuses exclusively on the weighted measures, we also report the more traditional, equally weighted, measures of the third and fourth moments for comparative purposes (see Table A3.2). Both methods of calculating skewness and kurtosis produce statistics that suggest similar conclusions.

A3.1 Kurtosis

For the Canadian data, it appears that kurtosis depends on the frequency over which the growth rates are calculated. Below the year-over-year horizon, kurtosis is very large (22.02 for monthly growth rates, 17.57 for quarterly changes). At longer horizons, kurtosis is much lower (7.82 for yearly growth rates, 6.31 for 36-month changes), but remains at problematic levels when compared to the kurtosis of 3 that corresponds to a normal distribution.

If a distribution is approximately normal, then the sample mean is an unbiased and efficient estimator of the population mean. However, the efficiency is sensitive to kurtosis. High kurtosis, and in particular, a leptokurtic distribution indicate that the mean is a less-efficient and less-robust estimator of the population or underlying mean price change than an order statistic such as the

18. We use 54 subindexes because disaggregation at this level provided us with the longest sample possible. Changes to the prices surveyed and to the basket made it difficult to extend the data back further.

19. See footnote 9.

median. Canadian measures of core inflation are based on the distribution of year-over-year price changes. At a year-over-year frequency, kurtosis averages 7.82; therefore, it is important to consider the weighted median as a robust estimator of the underlying population mean and, by extension, as a prospective measure of core inflation.

A3.2 Skewness

Skewness also varies with the frequency over which it is calculated. Seasonality in the monthly changes will contribute to skewness in the data when price changes are calculated over this horizon. As the horizon becomes longer, from a monthly to quarterly to yearly basis, skewness falls. On average, skewness does not seem to present a major problem for distribution of year-over-year changes, where the average weighted skewness is 0.15. For longer horizons, however, skewness increases again.

At the top of each of Figures A1–A5, we graph the weighted mean and the weighted median of the Canadian data to emphasize the problem that might be created by skewness. Note that for the month-over-month data, the weighted median seems to capture the central tendency of the data. This also appears to be the case for the 3-month-over-3-month and 12-month-over-12-month changes in the CPI. However, for the 24-month-over-24-month changes, the weighted median is increasingly below the weighted mean. In the 36-month-over-36-month changes, the weighted median consistently underpredicts the weighted mean. This demonstrates how it might be misleading to focus on a weighted median in the presence of skewness. Roger (1997) concludes that although the median is the most robust estimator, it is a biased estimator when the population is skewed. Roger finds that "slightly higher percentile of the price change distribution reliably corrects for the asymmetry of the distribution, while maintaining its efficiency and robustness." He therefore calculates an alternative order statistic (the 57th percentile) as the most efficient and robust estimator for New Zealand. However, since skewness is not a major problem on average at the year-over-year frequency, there seems to be no need to calculate an alternative order statistic to the 50th percentile for Canada, as Roger proposes for New Zealand.

A3.3 Seasonal adjustment

We also seasonally adjust the individual price change series using the ARIMA-X11 procedure. As shown in Table A3.3, this reduces both the weighted skewness and weighted kurtosis in the monthly and quarterly changes. Seasonal adjustment of the individual price changes reduces the weighted skewness for the 1986–98 period from 0.36 to 0.19 for the monthly changes and from 0.33 to 0.17 for the quarterly changes. This supports the view that some of the observed skewness and kurtosis reflects seasonality in price changes. Thus, weighted skewness may not characterize the Canadian data even at these higher frequencies. Kurtosis is also reduced although it remains at problematic levels. Kurtosis is 19.41 for monthly changes, compared to 22.02 in the unadjusted data, and 13.34 for quarterly changes, compared to 17.57 in the unadjusted data.

A3.4 Changes in the skewness in the Canadian data in the low-inflation period

Ball and Mankiw (1995) argue that in the presence of menu costs, the skewness of the cross-sectional distribution of price changes will be a predictor of inflation. Ball and Mankiw test this hypothesis by examining the correlation between the sample mean and sample skewness. They find evidence consistent with their theory.

Bryan and Cecchetti (1996) challenge the existence of this positive correlation between the mean and skewness in the distribution of price changes. Their Monte Carlo experiments suggest that this positive correlation is actually due to a large positive small-sample bias. The intuition is as follows. If we have a random draw from a symmetric distribution with mean zero, then draws that deviate from the population mean of the distribution will affect both the first and third moments of the distribution, leading to a correlation between the moments. They suggest that the thickness of the tails of the probability distribution from which the draws are taken will determine the likelihood of an extreme draw.[20] Therefore, the kurtosis determines the size of the small-sample bias. Their Monte Carlo experiments suggest that kurtosis above 4 results in a significant small-sample bias.

We do observe a positive correlation between the mean and the weighted skewness in Canadian data. In recent years, the weighted mean of the year-over-year price changes has fallen from 4.4 per cent for the January 1986 to December 1991 period to 1.6 per cent for the January 1992 to August 1998 period. At the same time, the average weighted skewness fell from 0.32 in the first period to 0.00 in the second period (see Table A3.4). The correlation between the weighted mean and weighted skewness in inflation is quite evident in Figure A3, for example. Interestingly, weighted kurtosis has also fallen from 9.72 in the first period to 6.11 in the second period, though it remains problematic. Moreover, there is much less variation in the measures of skewness and kurtosis (both weighted and unweighted) in the recent period of low inflation, suggesting that skewness and kurtosis may reach problematic levels less often in the current low-inflation environment.

The dramatic decline in weighted skewness and weighted kurtosis in the recent low-inflation period would suggest that there is no one underlying population of price changes. The distribution of price changes is evolving over time with the policy environment and the resulting inflation process.

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20. If you increased the variance of a normal distribution you would get the same result.

Table A3.1: Summary statistics for price change distributions of various horizons
Sample 86m1 to 98m8

	M/M	3M/3M	12M/12M	24M/24M	36M/36M
			Weighted Skewness		
Average	0.36	0.33	0.15	0.59	0.96
Std. dev	3.27	2.71	1.44	0.93	1.03
			Weighted Kurtosis		
Average	22.02	17.57	7.82	6.17	6.31
Std. dev	15.67	12.08	4.19	2.94	4.28

Table A3.2: Summary statistics for price change distributions
Equally weighted price changes: Sample 86m1 to 98m8

	M/M	3M/3M	12M/12M	24M/24M	36M/36M
			Skewness		
Average	0.29	0.25	0.19	0.46	0.74
Std. dev	2.73	2.27	1.31	0.79	0.89
			Kurtosis		
Average	15.99	13.48	7.31	5.58	5.69
Std. dev	9.45	7.18	3.76	2.23	3.76

Table A3.3: Summary statistics for price change distributions
Seasonally adjusted data & weights varied
Sample 1986m1 to 1998m8

	M/M	3M/3M
	Weighted Mean	
Average	0.22	0.69
Std. dev	0.19	0.45
	Weighted Skewness	
Average	0.19	0.17
Std. dev	3.13	2.35
	Weighted Kurtosis	
Average	19.41	13.34
Std. dev	15.87	10.71

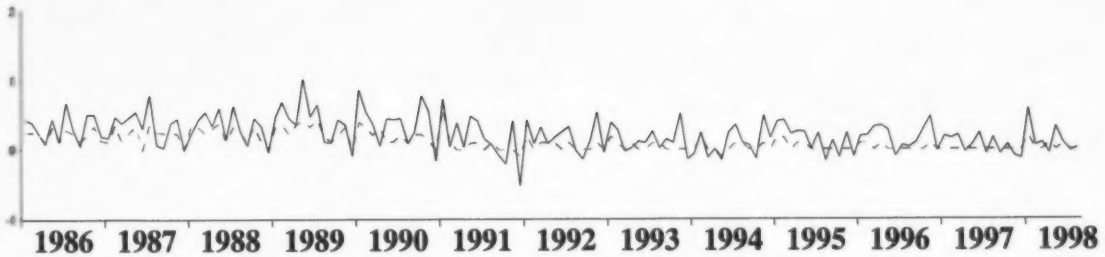
Table A3.4: Summary statistics for 12M/12M price change distributions

	1986m1 to 1991m12		92m1 to 98m8	
	weighted mean			
Average	4.40		1.60	
Std. dev	0.66		0.49	
	Unweighted	Weighted	Unweighted	Weighted
	Skewness			
Average	0.07	0.32	0.30	0.00
Std. dev	1.76	1.93	0.68	0.75
	Kurtosis			
Average	9.04	9.72	5.75	6.11
Std. dev	4.23	4.42	2.40	3.12

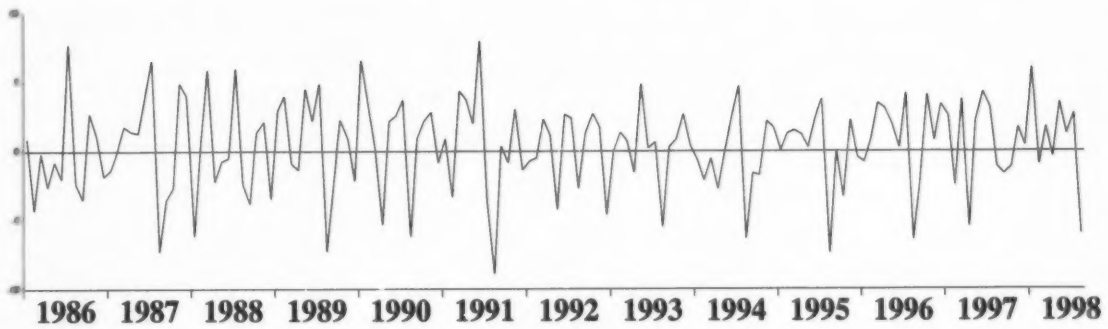
Figure A3.1: Month-over-month changes

Weighted Mean vs Weighted Median
Month over month growth of CPI, monthly data
Jan. 1986 to Aug. 1998

—— weighted mean
- - - weighted median



Skewness over sample
Month over month growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Kurtosis over sample
Month over month growth of CPI, monthly data
Jan. 1986 to Aug. 1998

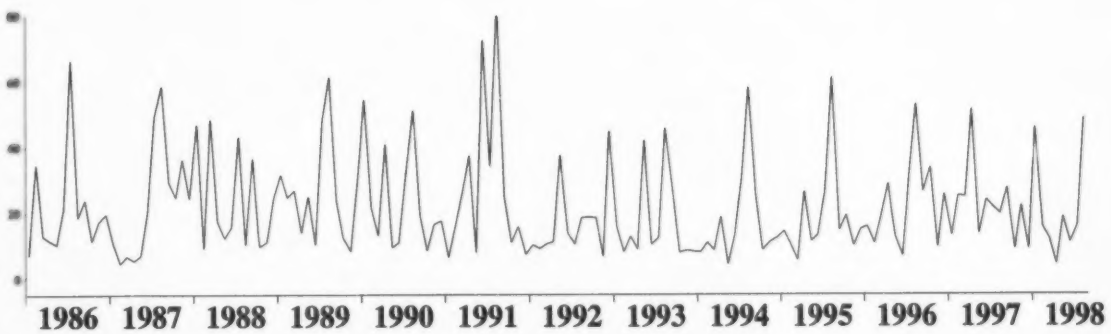
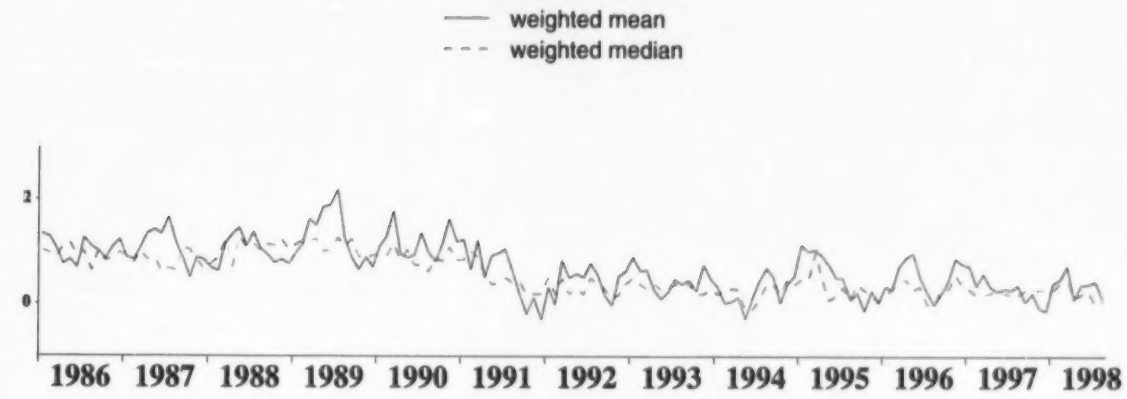
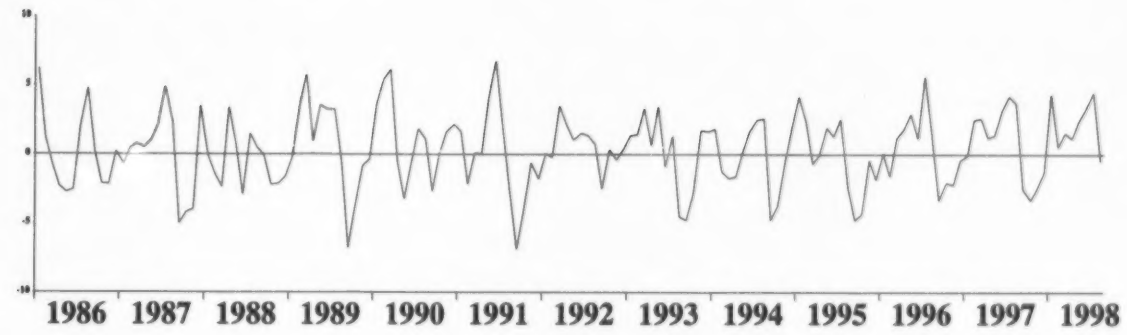


Figure A3.2: Quarter-over-quarter changes

Weighted Mean vs Weighted Median
Quarter over quarter growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
Quarter over quarter growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Kurtosis over sample
Quarter over quarter growth of CPI, monthly data
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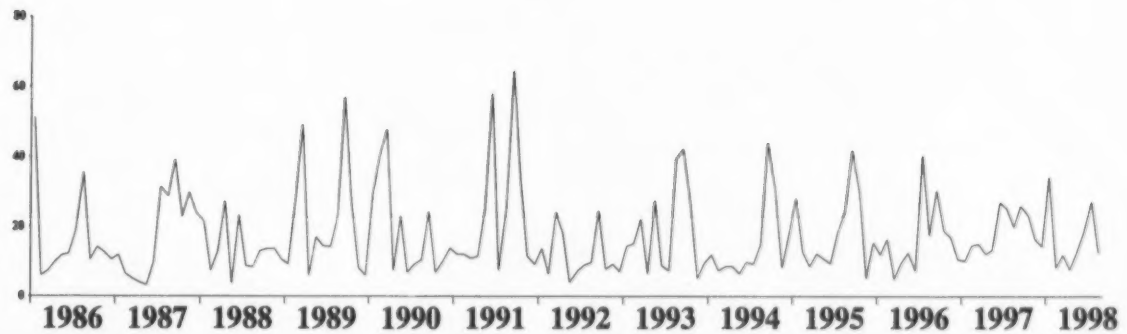
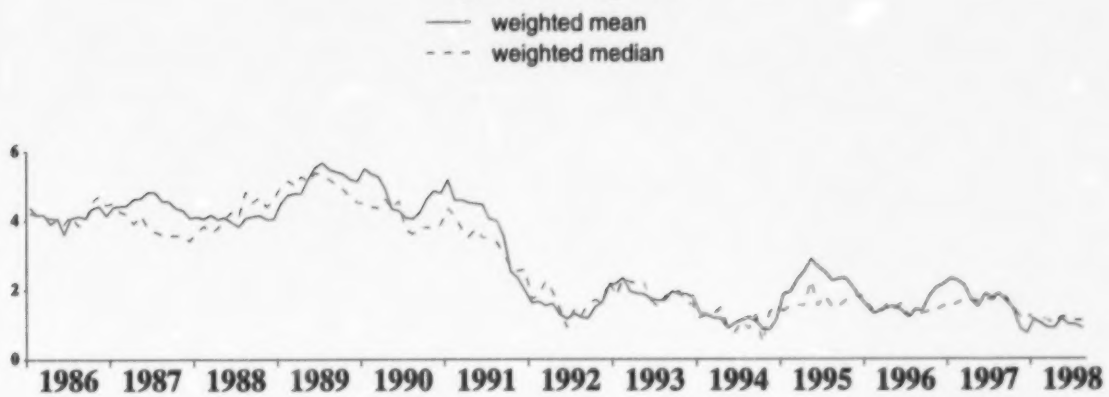
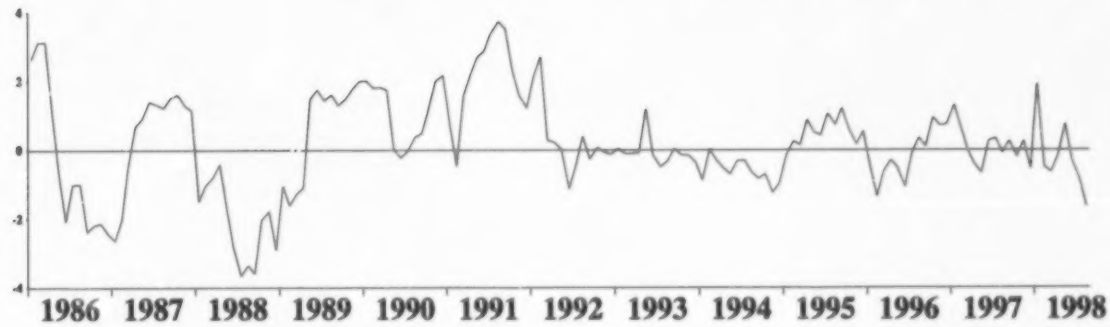


Figure A3.3: Year-over-year changes

Weighted Mean vs Weighted Median
Year over year growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
Year over year growth of CPI, monthly data
Jan 1986 to Apr 1998



Kurtosis over sample
Year over year growth of CPI, monthly data
Jan 1986 to Apr 1998

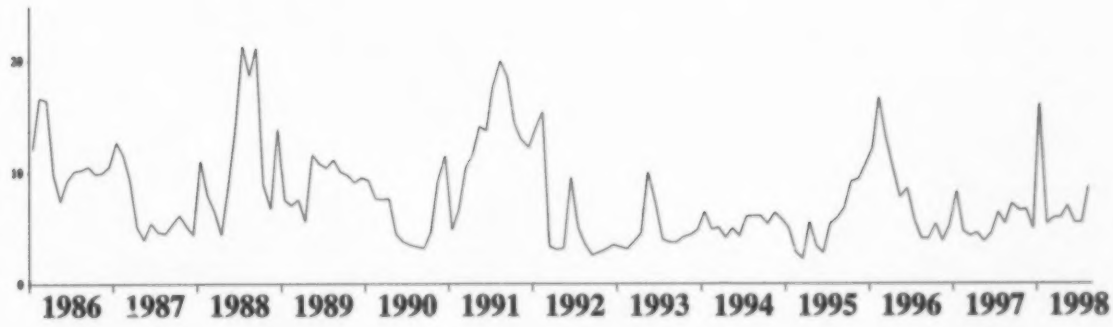
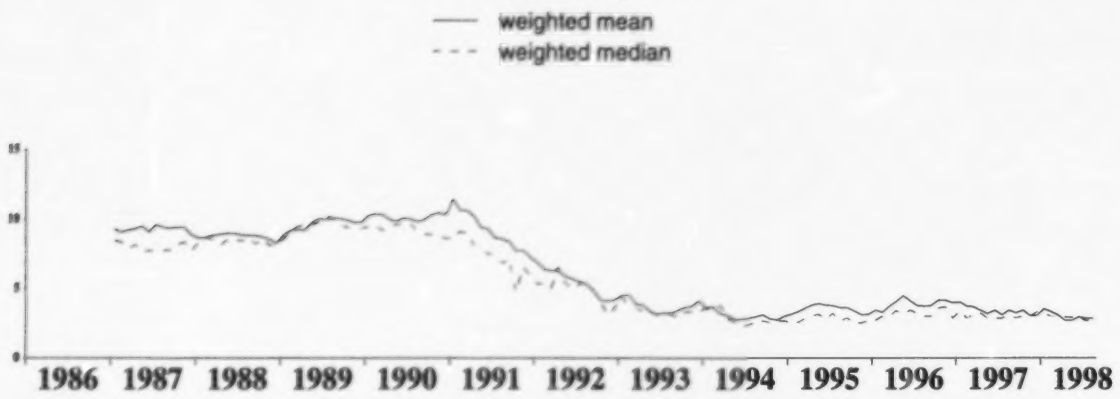
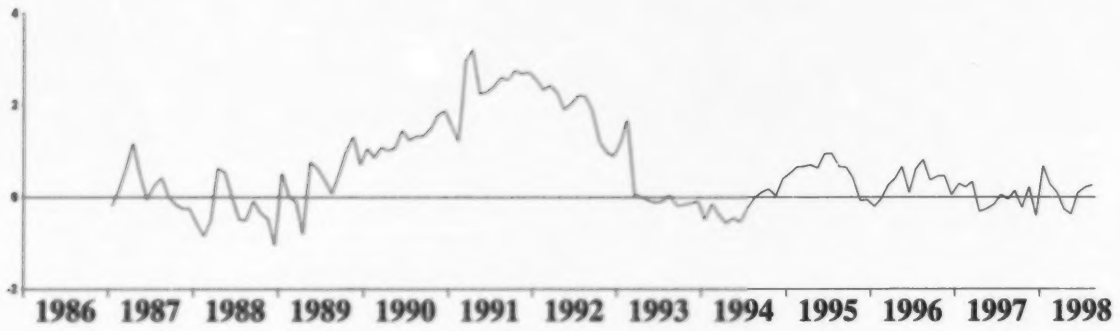


Figure A3.4: 24-month-over-24-month changes

Weighted Mean vs Weighted Median
24 months over 24 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



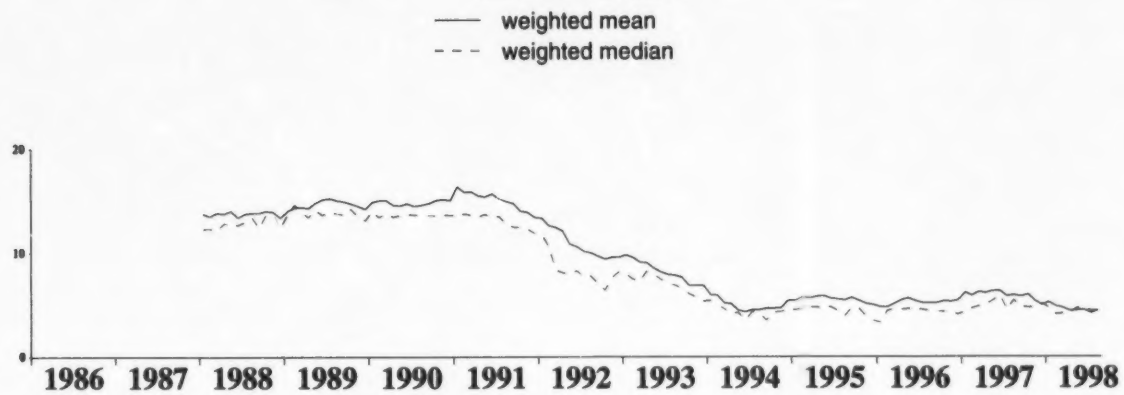
Skewness over sample
24 months over 24 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



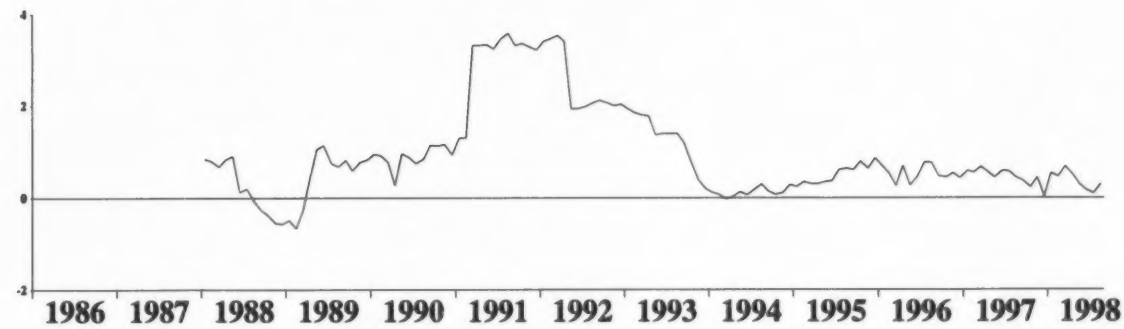
Kurtosis over sample
24 months over 24 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998

Figure A3.5: 36-month-over-36-month changes

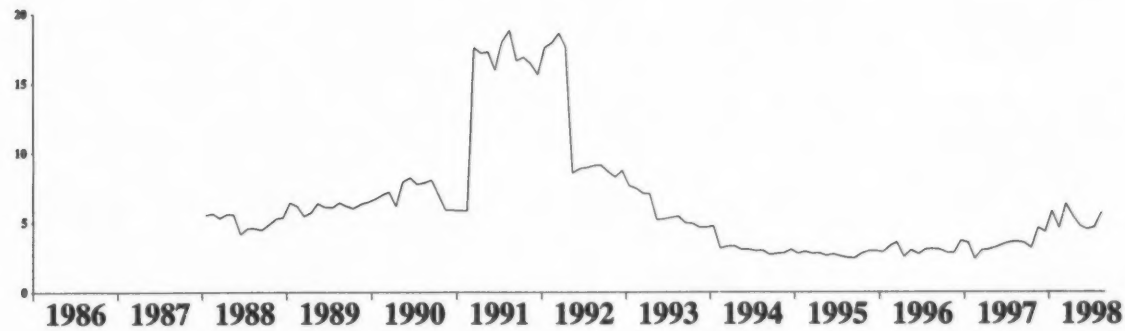
Weighted Mean vs Weighted Median
36 months over 36 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Skewness over sample
36 months over 36 months growth of CPI, monthly data
Jan. 1986 to Aug. 1998



Kurtosis over sample
36 months over 36 months growth of CPI, monthly data
Jan 1986 to Apr 1998



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